Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program Vital Signs Monitoring Plan

September 30, 2005

Prepared by:
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Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program

Vital Signs Monitoring Plan

September 30, 2005

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Because of the tremendous efforts of so many people in producing this vital signs monitoring plan, authorship of this document is unfortunately limited to those that have simply brought to print the analysis, vision, and contributions of so many people. We are able to acknowledge only a few of those people here.

This report builds on the strong foundation presented in the 2002 Heartland Phase I Report by Dr. Janet Eckhoff, Dr. Brent Frakes, Heather Parker, and Michael Williams. The strategic planning meeting reports, exhaustive information gathering, and the development of conceptual ecological models that were drafted during this phase are included in the numerous supplemental documents associated with chapters one and two.

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Our goal in producing this document has been simple: to guide future natural resource monitoring to benefit natural resource management in network parks. We trust that the cooperation that has produced this plan will continue to move this network towards that end.

EXECUTIVE SUMMARY

Knowing the condition of natural resources in national parks is fundamental to NPS's ability to manage park resources "unimpaired for the enjoyment of future generations." Funded by the Natural Resource Challenge, NPS has implemented a strategy to institutionalize natural resource inventory and monitoring. The effort was undertaken to ensure that the 270 park units with significant natural resources possess the information needed for effective, science-based resource management decision-making. The national strategy consists of a framework having three major components: 1) completion of basic resource inventories upon which monitoring efforts can be based; 2) creation of experimental prototype monitoring programs to evaluate alternative monitoring designs and strategies; and 3) implementation of ecological monitoring in all parks with significant natural resources.

Parks with significant natural resources have been grouped into 32 monitoring networks linked by geography and shared natural resource characteristics. The network organization will facilitate collaboration, information sharing, and economies of scale in natural resource monitoring. Parks within each of the 32 networks work together and share funding and professional staff to plan, design, and implement an integrated long-term monitoring program. The Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program (HTLN) is composed of fifteen National Park Service (NPS) units within the states of Arkansas, Indiana, Iowa, Kansas, Minnesota, Missouri, Nebraska, and Ohio. The member parks are Arkansas Post National Memorial (ARPO), Buffalo National River (BUFF), Cuyahoga Valley National Park (CUVA), Effigy Mounds National Monument (EFMO), George Washington Carver National Monument (GWCA), Herbert Hoover National Historic Site (HEHO), Homestead National Monument of America (HOME), Hopewell Culture National Historical Park (HOCU), Hot Springs National Park (HOSP), Lincoln Boyhood National Memorial (LIBO), Ozark National Scenic Riverways (OZAR), Pea Ridge National Memorial Park (PERI), Pipestone National Monument (PIPE), Tallgrass Prairie National Preserve (TAPR), and Wilson's Creek National Battlefield (WICR).

The complex task of developing ecological monitoring requires a front-end investment in planning and design to ensure that monitoring will meet the most critical information needs and produce ecologically relevant and scientifically credible data that are accessible to managers in a timely manner. The HTLN monitoring program was developed over four years with specific objectives and reporting requirements for each of three planning phases. This document is the final monitoring plan. This plan: 1) outlines HTLN monitoring goals and the planning process used to develop the monitoring program; 2) summarizes existing information concerning park natural resources and resource management issues across the network; 3) provides a conceptual model framework for HTLN park ecosystems; 4) selects and prioritizes vital signs; 5) presents a sampling framework for aquatic and terrestrial ecosystems in parks; 6) summarizes monitoring protocols;

7) describes the network's approach to data management, and 8) provides information on program administration, funding, and operations.

The diversity of ecosystems in HTLN parks, the geographic distribution of these parks, and differences in resource management priorities among parks are perhaps the greatest challenges facing the network. However, the vital signs selection process found that parks share a number of similar resource management issues and monitoring needs. The vital signs selection process also recognized that high priority park-specific needs should be addressed to the extent possible. This balance between identifying common needs and addressing park-specific issues will continue to be important as the HTLN implements long-term vital signs monitoring of parks.

The HTLN vital signs monitoring plan identifies the suite of vital signs for monitoring. Of these vital signs, the network will prepare and implement the following monitoring protocols over the next 2-4 years in selected parks:

Level 1	Level 2	Level 3	Network Vital Sign Name
Air and Climate	Air Quality	Ozone	Ozone
		Wet and Dry Deposition	Wet and Dry Deposition
		Visibility and Particulate Matter	Visibility and Particulate Matter
		Air Contaminants	Air Contaminants
	Weather and Climate	Weather and Climate	Weather
Geology And Soils	Geomorphology	Stream/ River Channel Characteristics	Fluvial Geomorphology
			Stream Habitat/ Riparian Assessment
		Surface Water Dynamics	Stream Discharge
	Water Quality	Water Chemistry	Core Water Quality Parameters
		Toxics	Pollutant Metals
		Aquatic Invertebrates and Algae	Aquatic Invertebrates—Prairie Streams
			Aquatic Invertebrates—Rivers
Biological Integrity	Invasive Species	Invasive/ Non-native Plants	Exotic Forest Plants
		Invasive/ Non-native Plants	Exotic Grassland Plants
	Focal Species or Communities	Wetland Communities	Wetland Plant Communities
		Grassland Communities	Prairie Community Structure, Composition, and Diversity
		Forest Vegetation	Forest Community Structure, Composition, and Diversity
		Fishes	Fish Community—Prairie Streams
			Fish Community—Ozark Rivers
		Birds	Land birds
		Mammals	Deer
		Threatened and Endangered Species and Communities	Missouri Bladderpod
			Ozark Hellbender
			Topeka Shiner
			Western Prairie Fringed Orchid
Ecosystem Patterns and Processes	Land Cover and Use	Land Cover and Use	Land Cover/Land Use

Network I&M staff and their cooperators make thousands of observations each year about plant and animal populations, communities, and their environments. In essence, the purpose of data management is to ensure that an accurate and complete record of those observations is maintained in perpetuity. The HTLN Data Management Plan identifies key data resources and processes to manage inventory and monitoring (I&M) data. Assuring and maintaining data integrity is fundamental to the HTLN mission and requires a considerable investment of staff time. Data management procedures follow five key steps: acquisition, verification, validation, analysis, and dissemination. In addition, storage, maintenance, and security issues apply to all stages of the data flow. As the plan is implemented, the network will likely manage as many as 90 databases.

Reporting is the process through which we derive information from the underlying data through analysis and interpretation for use by park managers. Vital signs monitoring reports will include: 1) annual summaries written for park and network managers; 2) five-year trend reports for park superintendents and natural resource managers; 3) internet websites for NPS staff and the general public; and 4) e-mail bulletins for park superintendents, natural resource managers, and the general public on-request. To promote efficient reporting, data management efforts during the summary and analysis phase focus on automation of routine reports. Summary analysis for annual reports of vital signs monitoring studies will include graphed results and descriptive statistics (mean, standard deviation, sample size) for all of the primary variables included in the project. Five to ten year trend reports will typically include correlation and trends analysis.

Administrative oversight for the program originates from the Board of Directors (BOD) and Network Technical Committee (NTC). The BOD, representing the superintendents of the fifteen parks, is charged with oversight of the network. The BOD comprises five superintendents that serve two year terms on a rotating basis. The NTC represents the natural resource managers of the 15 parks and serves as the scientific and operational body of the network that develops recommendations on how monitoring is implemented. The program coordinator is supervised by the Midwest Region I&M coordinator. In turn, the program coordinator, or his/her subordinates, supervise all I&M staff. In October 2003, the BOD and superintendents from parks in the prototype program approved integration of the Prairie Cluster Prototype Monitoring Program with the Heartland Network and adopted a staffing plan for the integrated program. The staffing structure reflects the intention of the network to implement monitoring primarily through NPS personnel. Currently the HTLN staff consists of ten permanent and three temporary employees centrally located at WICR and on the nearby campus of Southwest Missouri State University. The I&M staff includes project managers who oversee implementation of particular vital signs monitoring projects; technical experts who provide support in GIS, data management, statistical analysis, and survey design; and administrative staff.

Several sources of funding are combined to support operations of the HTLN. The two principle sources are vital signs monitoring funds from the Natural Resource Challenge ($651,600) and funds dedicated to operations of the Prairie Cluster Prototype ($505,000). In addition, NPS Water Resources Division contributes $82,000 for water quality monitoring and, for the past several years, FIREPRO has provided funds for joint monitoring efforts in Great Plains parks ($44,909). All funds are managed by the program coordinator under the oversight of the BOD.

An annual work plan is developed with input from the NTC and approved by the BOD that directs expenditure of funds to projects, parks, and offices. All I&M program funds must be strictly accounted for using a discrete project work element (PWE) codes and disclosed in an Annual Administrative Report.

HTLN will be subject to periodic reviews to ensure high program quality and accountability. Review of the draft network monitoring plan will be organized by the WASO monitoring leader and take place in 2005. In 2010 and every fifth year thereafter, a comprehensive review of program operations will be conducted. Peer review of monitoring protocols will be conducted by the MWR I&M coordinator upon their completion and prior to implementation.

CHAPTER 1: INTRODUCTION AND BACKGROUND

Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program (HTLN) Overview

HTLN Formation and Administration

The Heartland Inventory and Monitoring (I&M) Network and Prairie Cluster Prototype Monitoring Program (HTLN) was formed as a result of a merger between two co-located monitoring programs: the Heartland I&M Network and the Prairie Cluster Prototype Long-term Ecological Monitoring Program. Initially funded in 1994, the prototype program was one of 11 programs dedicated to leading the development of scientifically credible and cost-effective monitoring programs in the National Park Service (NPS). With funding received in 2001, the Heartland I&M Network is one of 32 NPS I&M networks assisting 270 parks with biological inventories and long-term vital signs monitoring. "Vital signs," as used by the National Park Service, are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, are known or hypothesized effects of stressors, or are elements that have important human values. The elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants, animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes). Monitoring networks allow parks to share a professional staff to serve parks with similar ecosystems and resource management issues. Compared to vital signs monitoring networks, prototype programs receive higher funding and staffing levels to support in-depth development of sampling designs, field methods, data management tools, and analytical techniques. In July 2004, the Prairie Cluster Prototype Long-term Ecological Monitoring Program and the Heartland I&M Network merged to increase cooperation, reduce redundancy, and achieve economies of scale. HTLN is located at Wilson's Creek National Battlefield in Republic, Missouri.

The fifteen HTLN parks extend across eight states (Arkansas, Indiana, Iowa, Kansas, Minnesota, Missouri, Nebraska, Ohio) and include a diversity of terrestrial and aquatic ecosystems associated with tallgrass prairies, Eastern deciduous forests, interior highlands, and the Mississippi floodplain (Table 1-1, Figure 1-1).

Prior to the merger, the Prairie Cluster Prototype Long-term Ecological Monitoring Program comprised seven parks: AGFO, EFMO, HOME, PIPE, SCBL, TAPR, and WICR. These parks share significant prairie, woodland, and prairie stream resources. Five of the prototype parks are also included in the HTLN, while AGFO and SCBL are parks in the Northern Great Plains I&M Network (NGPN). Once the NGPN is fully operational, the NGPN will take the lead in monitoring those parks. Maps of each HTLN park can be found in Appendix 1.

The Board of Directors approved revisions to the original Heartland I&M Network charter (Supplemental Document 1) at the annual network meeting in August 2004 to join the two programs under the same administrative structure. As outlined in the charter, the program operates under the direction of a network coordinator. The coordinator supervises network staff and administers the program budget. The coordinator is supervised by the regional I&M coordinator. A Board of Directors representing the superintendents provides administrative oversight for the HTLN. The HTLN Technical Committee provides scientific and operational guidance for monitoring. Two primary sources fund the program. The original prototype program funds are included in WICR base accounts. The Washington Office (WASO) holds funds designated for the Heartland I&M Network as a part of the NPS Natural Resource Challenge. The NPS Water Resources Division also provides funding for HTLN to monitor for impaired and pristine waters in close coordination with vital signs monitoring. Within the integrated program, an original Prairie Cluster Prototype Monitoring Program park will retain a designation as a "prototype park" to recognize parks where in-depth, ongoing monitoring will be continued. In this way, the monitoring protocol development mission of the prototype program will be retained within HTLN.

Table 1-1. NPS park units in the Heartland I&M Network and Prairie Cluster Prototype Monitoring Program

Park	Code	State	Size (acres)
Arkansas Post National Memorial	ARPO	AR	758
Buffalo National River	BUFF	AR	94,293
Cuyahoga Valley National Park	CUVA	OH	32,861
Effigy Mounds National Monument	EFMO	IA	2,526
George Washington Carver National Monument	GWCA	MO	210
Lincoln Boyhood National Memorial	LIBO	IN	200
Herbert Hoover National Historic Site	HEHO	IA	187
Homestead National Monument of America	HOME	NE	195
Hopewell Culture National Historic Park	HOCU	OH	1,170
Hot Springs National Park	HOSP	AR	5,550
Pipestone National Monument	PIPE	MN	282
Pea Ridge National Military Park	PERI	AR	4,300
Tallgrass Prairie National Preserve	TAPR	KS	10,894
Ozark National Scenic Riverways	OZAR	MO	80,785
Wilson's Creek National Battlefield	WICR	MO	1,750

Rationale for Network Monitoring

The network approach is designed to minimize redundancy, maximize cost effectiveness, and increase consistency in data collection and information transfer. The amount of funding available for vital signs monitoring would allow most parks to monitor only a few indicators. A key efficiency of the network approach is to identify and monitor a core set of ecosystem attributes and resource/stressor relationships that are important across a group of parks. In addition to increased efficiency, applying standard monitoring approaches across ecoregions will result in greater potential for comparison and explanation in the resulting datasets. NPS adopted the strategic approach of encouraging networks and parks to seek partnerships with federal, tribal, and state agencies and adjacent landowners to leverage monitoring funding. Ideally, network monitoring would form the middle tier of an integrated monitoring framework, linking national and regional monitoring programs to park-specific monitoring efforts (Figure 1-2).

Figure 1-1. Location of Heartland I&M Network and Prairie Cluster Prototype Monitoring Program parks.

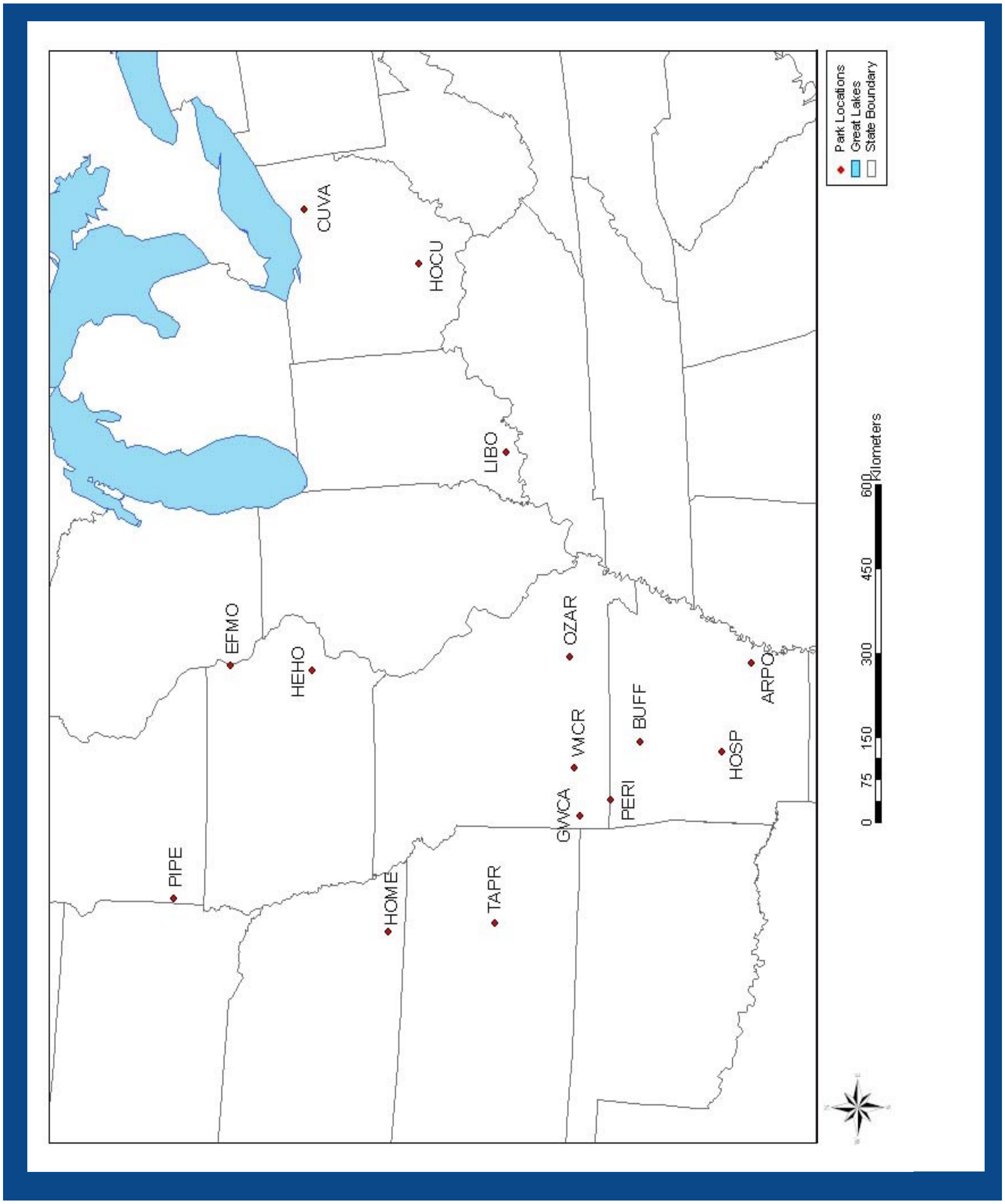
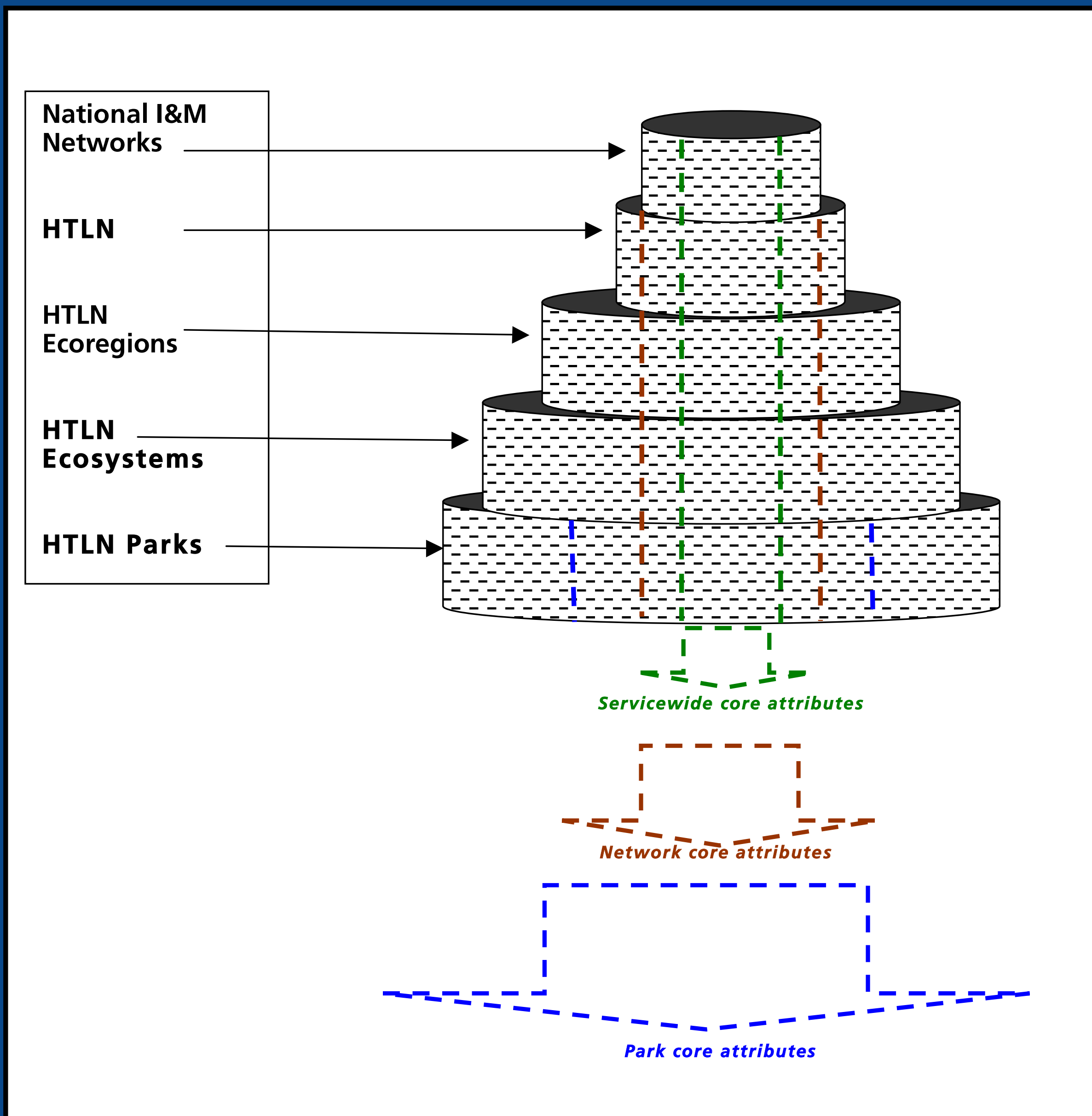


Figure 1-2. Depiction of network monitoring in relation to other efforts throughout the National Park Service (adopted from U.S. Forest Service)



Justification for Vital Signs Monitoring

Role of Monitoring

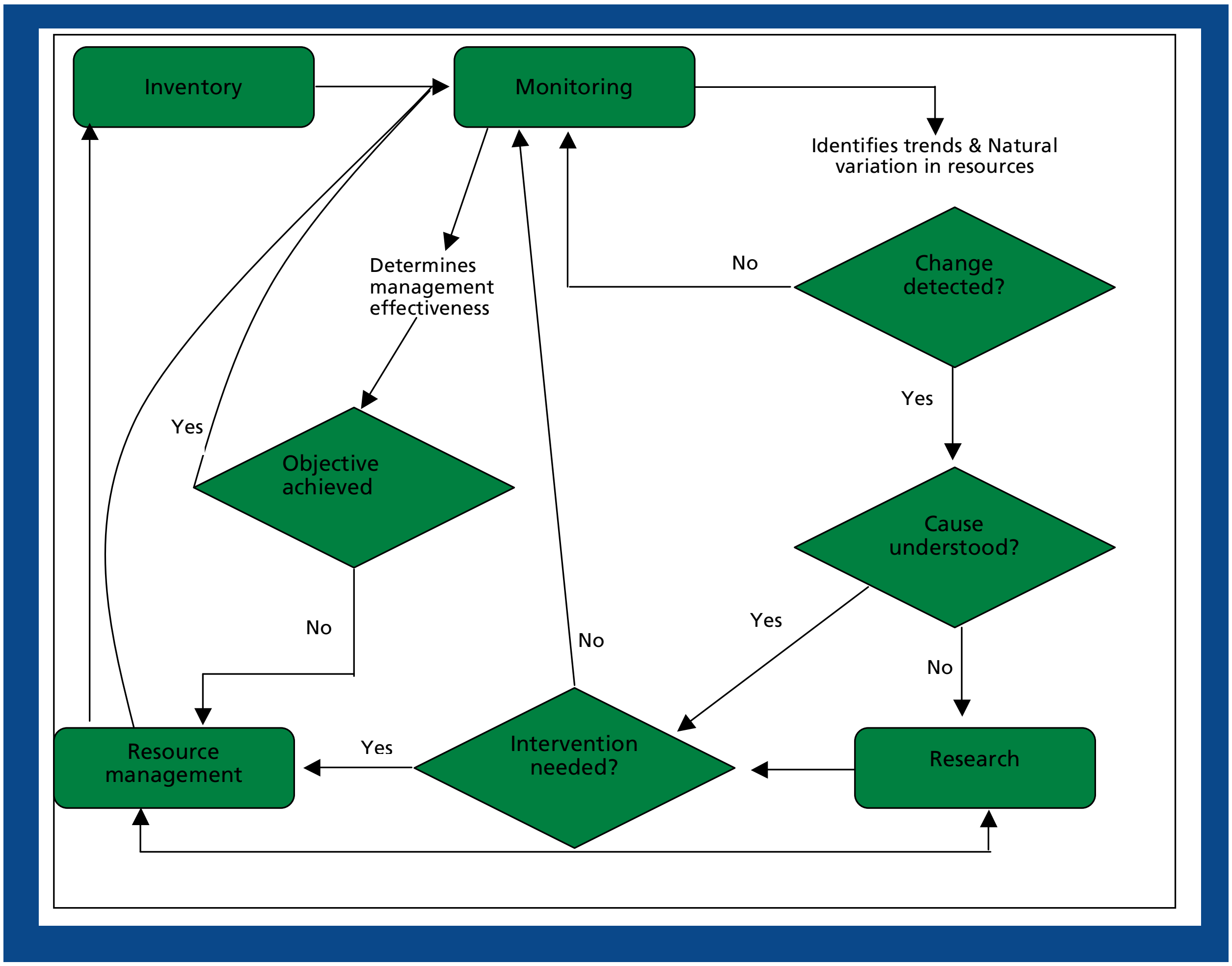
As NPS managers are confronted with increasingly complex and challenging natural resource management issues, knowing the condition of natural resources in national parks is fundamental to the NPS mission to manage resources in a manner that leaves them "unimpaired for the enjoyment of future generations". Natural resource monitoring provides site-specific information needed to understand and identify change in complex, variable, and imperfectly understood natural systems and to determine whether observed changes are within natural levels of variability or indicate undesirable influences (Figure 1-3). Monitoring may be used to determine trends in the condition of park resources, to assess the efficacy of management practices and restoration efforts, and to provide early warning of impending threats. Ecological monitoring establishes reference conditions for natural resources from which future changes can be detected. Over the long term, these "benchmarks" help define the normal limits of natural variation, may become standards with which to compare future changes, provide a basis for judging what constitutes impairment, and help identify the need for corrective management actions. Understanding the dynamic nature of park ecosystems and the consequences of human activities is essential for management decision-making aimed to maintain, enhance, or restore the ecological integrity of park ecosystems and to avoid, minimize, or mitigate ecological threats to these systems (Roman and Barrett 1999). The intent of the NPS monitoring program is to track a subset of physical, chemical, and biological elements and processes of park ecosystems, known as "vital signs," that are identified as the most significant indicators of ecological condition for those specific resources that are of greatest concern to each park. This subset of vital signs is part of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological, plant, and animal resources, and the various ecological, biological, and physical processes acting on these resources. In situations where natural areas have been so highly altered that physical and biological processes no longer operate (e.g., control of fires and floods in developed areas), information obtained through monitoring can help managers understand how to implement the most effective natural resource management.

Intrinsic Versus Anthropogenic Variability (Thomas et al. 2003, Miller et al. 2003)

Detecting anthropogenic change is complex because ecosystems are inherently dynamic and spatially heterogeneous. Yet an important goal of monitoring is to differentiate the effects of intrinsic variability from those resulting from human-induced patterns of change (Noon et al. 1999, Osenberg et al. 1994). The aims of characterizing natural variability are to understand how driving processes yield different effects from site to site, to reconstruct how these processes influenced systems in the past, and to predict future outcomes (Landres et al. 1999). Historical ecology informs us about the pathways that brought ecosystems to their current state and may help identify anomalous conditions (Swetnam et al. 1999).

Thus, the historic range of natural variability provides an important context for evaluating current anthropogenic effects although changes in atmospheric chemistry, climatic conditions, and land-use patterns will likely render historic patterns of variability less and less attainable over time.

Figure 1-3. Relationships between monitoring, inventory, research and natural resource management (modified from Jenkins et al. 2002)



Legislation, Policy, and Guidance

In establishing the first national park in 1872, Congress "dedicated and set apart (nearly 1,000,000 acres of land) as a … pleasuring ground for the benefit and enjoyment of the people" (16 U.S.C. 1 § 21). By 1900 a total of five national parks had been established, along with additional historic sites, scenic rivers, recreation areas, monuments, and other designated units. Each unit was to be administered according to its individual enabling legislation, but had been created with a common purpose of preserving the "precious" resources for public benefit. Sixteen years later the passage of the NPS Organic Act of 1916 (16 U.S.C. 1 § 1) established and defined the mission of the NPS:

> "The service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified … by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

Congress reaffirmed the declaration of the Organic Act vis-à-vis the General Authorities Act of 1970 (16U.S.C. 1a-1a8) and effectively ensured all park units be united into the 'National Park System' by a common purpose of preservation, regardless of title or designation. In 1978, the NPS's protective function was further strengthened when Congress again amended the Organic Act to state "…the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established…" thus further endorsing natural resource goals of each park. A decade later, park service management policy again reiterated the importance of this protective function of the NPS to "understand, maintain, restore, and protect the inherent integrity of the natural resources" (NPS 2001).

The general approach to the management of park natural resources is clearly established in Chapter Four of the NPS Management Policies (NPS 2001).

> "The Natural resources will be managed to preserve fundamental physical and biological processes, as well as individual species, features, and plant and animal communities. The Service will not attempt to solely preserve individual species (except threatened or endangered species) or individual natural processes; rather, it will try to maintain all the components and processes of naturally evolving park ecosystems, including the natural abundance, diversity, and genetic and ecological integrity of the plant and animal species native to those ecosystems. Just as all components of a natural system will be recognized as important, natural change will also be recognized as an integral part of the functioning of natural systems. By preserving these natural components and processes in their natural condition, the Service will prevent resource degradation, and therefore avoid any subsequent need for resource restoration.

> In managing parks to preserve naturally evolving ecosystems, and in accordance with requirements of the National Parks Omnibus Management Act of 1998, the Service will utilize the findings of science and the analyses of scientifically trained resource specialists in decision-making."

Based on this policy, NPS has adopted a science-based, ecosystem approach to natural resource management.

Recent and specific requirements for a program of inventory and monitoring park resources are found in the National Parks Omnibus Management Act of 1998 (P.L. 105-391). The intent of the act is to create an inventory and monitoring program that may be used "to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources. Again the 2001 NPS management policies specifically direct NPS to inventory and monitor natural systems in efforts to inform park management decisions:

> "Natural systems in the national park system, and the human influences upon them, will be monitored to detect change. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions" (NPS 2001).

In addition to the legislation directing the formation and function of the National Park System, a number of laws protect not only the natural resources within national parks and other federal lands, but they address environmental compliance in the United States. Many of these federal laws require natural resource monitoring within national parks. A summary of legislation, policy, and executive guidance having a direct bearing on natural resource monitoring in the NPS is presented in Appendix 2.

HTLN Parks Enabling Legislation

The HTLN includes four National Monuments, two National Memorials, two National Parks, a National Battlefield, a National Historic Park, a National Historic Site, a National Military Park, a National Preserve, a National Scenic Riverway, and a National River. In 1970, Congress elaborated on the 1916 NPS Organic Act, recognizing all of these designations as having equal legal standing in the National Park System.

The enabling legislation of a park states the natural and cultural resource values that are to be protected. Along with national legislation, policy, and guidance, a park's enabling legislation provides justification and, in some cases, specific guidance for park resource management programs, including inventory and monitoring. See Appendix 3 for an overview of HTLN parks' enabling legislation.

Government Performance and Results Act

The Government Performance and Results Act (GPRA) guides the management of national parks in outlining measurable performance goals and requiring NPS to demonstrate the attainment of those goals to the U.S. Congress. For NPS, four overarching goals provide direction for developing more specific goals.

1. Category I goals preserve and protect park resources.
2. Category II goals provide for the public enjoyment and visitor experience of parks.
3. Category III goals strengthen and preserve natural and cultural resources and enhance recreational opportunities managed by partners.
4. Category IV goals ensure organizational effectiveness.

The HTLN vital signs monitoring plan clearly assists in meeting numerous Category I goals and augments Category II and III goals. The servicewide goal pertaining to natural resource inventories specifically identifies the objective of inventorying the resources of the parks as an initial step in protecting and preserving park resources (GPRA Goal Ib1). The vital signs monitoring plan identifies the indicators or "vital signs" of the network (GPRA Goal Ib3a) and will be implemented to detect trends in resource condition (GPRA Goal Ib3b). In addition to the national strategic goals, each park has a five-year plan with specific park GPRA goals. GPRA goals relevant to HTLN parks natural resource monitoring and management are presented in Table 1-2. Park-specific goals are presented in Appendix 4.

HTLN Monitoring Program Audiences

HTLN monitoring information is relevant to a variety of audiences. First and foremost, park resource managers will use monitoring information to make informed management decisions and improve natural resource stewardship. Program work will also be of interest to park interpretation staff, maintenance personnel, and law enforcement officers. Detection and interpretation of long-term trends enables park superintendents to bring scientifically credible data to legal and political arenas. On a national scale, NPS will have a means to assess natural resource trends across the national parks. Federal, state, and local agency partners and neighboring landowners facing similar natural resource problems will benefit from lessons learned from HTLN monitoring. Academic and agency scientists will likely find HTLN monitoring data to be an asset for studies of ecosystem structure and function. Monitoring will also provide information and examples for science education. The broadest audience that will benefit from this program and its products is the public who visit the parks. These partnerships will lead to additional interest and leverage cooperation to support vital signs monitoring.

Background Information to Support Vital Signs Monitoring

Overview of Meetings to Identify Park Monitoring Needs

During the monitoring planning process, HTLN staff designed a series of workshops and meetings and invited subject matter experts to characterize the monitoring needs of the network parks (Table 1-3). The HTLN staff and technical committee distributed information prior to workshops, reported the outcome of the workshops, and summarized material submitted by the parks for the HTLN Phase I Report (Eckhoff et al. 2002). Objectives and accomplishments of the workshops are summarized here, and complete workshop reports are available in Supplemental Documents 2 through 8.

Table 1-2: Summary table of HTLN Park GPRA goals

General category	GPRA Goal #	Parks
Resources maintained	1a	HEHO
Disturbed lands restored	1a01A	CUVA, HOCU, OZAR
Disturbed lands restored	1a09B	OZAR
Disturbed lands restored	1a1A	ARPO, BUFF, CUVA, EFMO, HOSP, OZAR, PIPE, WICR
Disturbed lands restored	1b01A	OZAR
Exotic vegetation contained	1a1B	CUVA, EFMO, GWCA, HOCU, HOSP, OZAR, PIPE, WICR
Natural resource inventories acquired or developed	1b01	PERI, PIPE, TAPR
Stable federal T&E species or species of concern populations	1a2D	PIPE
Stable federal T&E species or species of concern populations	1a2X	ARPO, CUVA, GWCA, WICR
Stable federal T&E species or species of concern populations	1b02D	PIPE
Vital signs for natural resource monitoring identified	1b3a	ARPO, BUFF, CUVA, EFMO, GWCA, HEHO, HOCU, HOME, HOSP, LIBO, OZAR, PERI, PIPE, WICR, TAPR
Vital signs for natural resource monitoring identified	1b3b	ARPO, BUFF, CUVA, EFMO, GWCA, HEHO, HOCU, HOME, HOSP, LIBO, OZAR, PERI, PIPE, WICR, TAPR
Water quality improvement	1a04	BUFF, HOSP, WICR
Water quality improvement	1a4	CUVA, HOSP, OZAR, PIPE
Water quality improvement	1b1	BUFF
Wildlife habitat protected	1a01A	OZAR
Wildlife habitat protected	1a02c	BUFF
Wildlife habitat protected	1a02D	GWCA, WICR
Wildlife habitat protected	1a2A	BUFF
Wildlife habitat protected	1a9B	OZAR

Table 1-3. Summary of HTLN vital signs monitoring planning meetings

Workshop	Location	Dates	Description
Initial Monitoring Workshops	Wilson's Creek NB Republic, MO	February and March 2000	Workshops included taxonomic experts and NPS staff. A day of each workshop was devoted to program planning. Prior to the meeting, park staff answered questionnaires about their resource management and monitoring needs. Stressors that may affect these resources along with monitoring indicators were enumerated. Proposed monitoring projects were ranked using the Analytical Hierarchy Process (Peterson et al. 1995) (Supplemental Document 2).
Aquatic Resources Monitoring Workshop I	Hot Springs NP Hot Springs, AR	April 2001	A multidisciplinary panel of invited experts and NPS staff met to define specific aquatic monitoring objectives for each park and to identify a list of candidate indicators for further review. The participants assembled a generic list of 20 ecological indicators, differentiating between chemical, physical, and biological indicators. Five of these indicators (temperature, turbidity, dissolved oxygen, pH, and conductivity) constitute the NPS Water Resources Division's "core set" of water quality indicators (Supplemental Document 4).
Aquatic Resources Monitoring Workshop II	University of Missouri-Columbia Columbia, MO	October 2001	Participants included aquatic professionals from NPS, the United States Geological Survey, and the University of Missouri. The group discussed the spatial extent of the final monitoring plan and made assignments for completion of the aquatic portion of the HTLN Monitoring Plan.
Terrestrial Monitoring Workshop	Cuyahoga Valley NP Brecksville, OH	November 2001	The workshop included NPS resource professionals and invited ecologists. Parks specified management objectives, monitoring objectives, and monitoring questions for high priority management issues. Participants reviewed these issues and developed testable monitoring questions, while identifying appropriate indicators.
Aquatic Resources Monitoring Workshop III	University of Missouri-Columbia Columbia, MO	October 2002	The primary objectives of the workshop were to select a set of tentative indicators that would satisfy the monitoring objectives of parks with significant aquatic ecosystems and to draft preliminary monitoring designs. The participants addressed the monitoring needs of parks with impaired water bodies and drafted a framework for aquatic monitoring in parks with outstanding or significant water resources. Significant concerns of individual parks not already addressed were considered (Supplemental Document 5).
Land Use/Land Cover Change Workshop	University of Arkansas-Monticello Monticello, AR	December 2002	NPS staff and remote sensing specialists met to evaluate the role of GIS in land-use change monitoring. Participants discussed available land use classification systems and explored the steps, equipment, and personnel requirements (Supplemental Document 3).
Aquatic Resources Monitoring Workshop IV	Buffalo River NP Harrison, AR	February 2003	A final aquatic workshop was held to implement the action plan recommended at the October 2002 workshop (Supplemental Document 6).
Phase I Roadmap Workshop	Wilson's Creek NB Republic, MO	March 2003	The purpose of the workshop was to define a shared expectation regarding report content and the process to complete the network's phase I report (Supplemental Document 7).
Vital Signs Prioritization Workshop	St. Louis, MO	July 2003	The purpose of the workshop was to generate a defensible prioritized list of vital signs designed to track long-term ecological trends that represented park management concerns (Supplemental Document 8).

Overview of Monitoring in HTLN Parks

Documentation and review of existing monitoring provided a basis for evaluating where monitoring is adequate, where additional monitoring is needed, and which monitoring studies should be continued or expanded. In Spring 2002, HTLN initiated a data mining project to catalog previous monitoring in network parks (Supplemental Document 9). The objectives were to 1) locate spatial, tabular, and bibliographic data related to natural resources; 2) evaluate integrity of data based on specified criteria; 3) generate metadata and enter in to Dataset Catalog, GIS Clearinghouse and NRBib as necessary; and 4) flag important datasets for further review for potential incorporation into the monitoring plan. Important datasets are included as results from the data mining process (Supplemental Document 9). These databases will retain institutional knowledge lost when employees move to new positions. Documentation of existing inventory, monitoring, and research work is envisioned as an on-going function of the HTLN data manager.

Because air quality and water quality monitoring are expensive and transcend park boundaries, existing monitoring efforts are described here in detail.

Air Quality Monitoring

The NPS Air Resources Division (ARD) has developed a report describing the on-site and/or nearby off-site ambient air monitoring data relevant to HTLN parks (Supplemental Document 10). Findings include:

1. There are no Class I areas.
2. All HTLN parks have at least one NADP wet deposition monitor within 100 miles.
3. Eight HTLN parks have a CASTNet dry deposition monitor within 150 miles.
4. Baseline Water Quality Data Inventory and Analysis reports from eleven network parks indicate surface waters in HTLN are not sensitive to atmospheric deposition.
5. Nine HTLN parks have an IMPROVE visibility monitor within 100 miles.
6. All HTLN parks have at least one ozone monitor within 70 miles, although the monitor must be within 25 miles to have high confidence in the data.
7. All HTLN parks have one or more vascular plant species identified as appropriate biomonitors for ozone-induced foliar injury.

ARD also provided an ozone injury to vegetation risk assessment for each park (Supplemental Document 11). The risk of ozone injury varies across parks from low to high. Air quality information, including data on ozone, visibility, UVB radiation, atmospheric deposition, and emissions is updated and available for parks and networks in the NPS Air Resources Information System (NPS 2004a, http://www2.nature.nps.gov/air/Permits/ARIS/networks/htln.htm). Because of the expense of establishing an air quality monitoring station, air quality monitoring in HTLN will most likely be limited to collecting and summarizing data from air quality monitoring stations near parks. Portable air monitoring stations may be installed at HTLN parks to confirm the interpolation between permanent air monitoring stations.

Water Quality Monitoring

In FY 2001, HTLN developed a cooperative agreement with the University of Kansas to gather required aquatic information for the HTLN monitoring plan. Specific tasks under the agreement were to: 1) summarize existing state water quality standards and reference sites applicable to waters within each network park (Supplemental Document 12), 2) summarize state and national aquatic biological assessment methods (Supplemental Document 13), and 3) recommend specific monitoring designs for chemical, physical, and biological measurements given each park's monitoring objectives. In FY 2002, the HTLN extended the cooperative agreement with University of Kansas to include the following: 1) update water quality monitoring data collected at each park unit since publication of the Water Resource Division Baseline Water Quality Data Inventory and Analyses reports and integrate with existing data in an Access database, 2) summarize and analyze water quality data, and 3) integrate all work (including FY01 work) into a GIS format.

Prairie Cluster Prototype Long-term Ecological Monitoring Program Efforts

At the time that HTLN formed, the Prairie Cluster Prototype Long-term Ecological Monitoring Program already had a well-established monitoring program including on-going monitoring and new protocol development. Established, on-going monitoring projects are highlighted below:

1. Vegetation monitoring in prairies and woodlands-documents changes in plant species composition and structure in prairies and woodlands, especially in relation to resource management (fire management, restoration, grazing). Field methods in grasslands are based on those developed to monitor prairies at the Konza Prairie Long Term Ecological Research Program in Manhattan, Kansas.
2. Dead and downed fuels monitoring-records fuel loads in fuel class categories.
3. Aquatic invertebrate monitoring-measures aquatic invertebrate community as an indicator of aquatic ecosystem health.
4. Rare plant monitoring-tracks changes in the abundance and flowering of the Missouri bladderpod at WICR and the western prairie fringed orchid at PIPE.
5. Rare animal monitoring-measures annual differences in prairie dog population size at SCBL and in Topeka shiner populations at PIPE and TAPR.
6. Grassland bird monitoring-uses distance methods to examine changes in the grassland bird composition and abundance in relation to habitat at TAPR.
7. Fish community monitoring-assesses changes in fish community composition using seine nets.
8. Water quality monitoring-conducted in conjunction with projects 3, 5, and 7 listed above.

Park Ecosystems and Significant Natural Resources

Prior to vital signs selection, specific information on park ecosystems and natural resources was evaluated. An overview of park ecosystems is available in Supplemental Document 14. Network staff used several sources of information to summarize park-specific ecological information and significant natural resources, including written responses from park managers, input from meetings, and park planning documents. The information is presented in a narrative form in Supplemental Document 15. Significant natural resources are summarized in Table 1-4. Designation of a resource as significant was based on: 1) relevance to park mission, 2) national, regional or local conservation value, 3) ecological role or function of the resource within park ecosystems, or 4) value placed on the resource by park visitors.

Table 1-4. Summary of significant natural resources for Heartland I&M Network and Prairie Cluster Prototype Monitoring Program parks

	ARPO	BUFF	CUVA	EFMO	GWCA	HEHO	HOCU	HOME	HOSP	LIBO	OZAR	PERI	PIPE	TAPR	WICR
Water Resources															
perennial	X	X	X	X	X	X	X	X	X		X	X	X	X	X
intermittent/ephemeral		X	X	X							X			X	
cold springs		X	X		X				X		X		X	X	X
geothermal springs									X						
seeps		X	X		X				X		X			X	X
natural flow regime		X	X								X				
outstanding natural resource waters		X	X				X		X		X				
Unique Habitats															
canebrakes	X	X									X				
caves		X									X	X			X
glades		X							X		X	X			X
goat prairies				X											
isolated wetlands			X												
mesic bur oak forest								X							
old-growth forest									X						
post oak savannas		X									X	X			X
riparian wetlands	X	X	X	X	X	X	X	X	X		X	X	X	X	X
Dominant Vegetation Communities															
basswood-maple forest				X											
cypress-tupelo forest	X														
riparian forest		X	X	X	X	X	X	X	X		X		X	X	X
mesic mixed hardwood forest	X		X				X			X					
northern hardwood forest			X												
oak-hickory forest		X	X	X			X		X	X	X	X	X		X
oak-hickory-pine forest	X	X							X		X				
SE bottomland forest	X														
tallgrass prairie				X	X	X		X				X	X	X	X

Table 1-4. (Continued)

	ARPO	BUFF	CUVA	EFMO	GWCA	HEHO	HOCU	HOME	HOSP	LIBO	OZAR	PERI	PIPE	TAPR	WICR
Species of Concern (incl. T&E species) See Appendix 5	X	X	X	X	X	X			X	X	X		X	X	X
Communities of Concern															
amphibian	X				X	X	X								
bird							X				X		X	X	
butterfly						X		X					X	X	
cave invertebrate		X									X				X
fish		X									X			X	X
mussel		X									X				
reptile	X				X	X	X								
stream macro-invertebrates		X						X			X		X		X
Geologic Features															
karst features		X									X	X			X
sioux quartzite outcrop													X		
Unfragmented Landscape		X	X								X			X	
Soil	X					X									

In addition to the significant natural resources in Table 1-4, river and stream stretches listed under the Clean Water Act's 303d list within HTLN parks are also high priorities for management action (Table 1-5). These streams are known to exceed Environmental Protection Agency standards for at least one water quality parameter, rendering them unsuitable for recreational use, fish consumption, or aquatic life.

Table 1-5. Impaired (303d-listed) waters within Heartland I&M Network and Prairie Cluster Prototype Monitoring Program parks

Park	State	Impaired Segment	Most Significant Pollutant	TMDL Priority
CUVA	OH	Cuyahoga River (Yellow Creek to Brandywine Creek)	organic enrichment	high
CUVA	OH	Brandywine Creek	organic enrichment	high
CUVA	OH	Cuyahoga River (Brandywine Creek to Tinkers Creek)	organic enrichment	high
CUVA	OH	Tinkers Creek	organic enrichment	high
CUVA	OH	Chippewa Creek	ammonia	high
HOCU	OH	Scioto River	organics	high
WICR	MO	Wilson Creek	unknown toxicity	medium
OZAR	MO	Jack's Fork	fecal coliform	high
PIPE	MN	Pipestone Creek	fecal coliform	?
EFMO	IA	Yellow River	fecal coliform	high

A number of the HTLN natural resources are regionally important. Estimates for the loss of tallgrass prairie range from 82.6% to 99.9%, which is greater than the percentage loss for any other U.S. ecosystem (Samson and Knopf 1995 cited in Samson, Knopf, and Ostlie 1998). For this reason, the intact prairie vegetation and even the restored remnant prairies in HTLN parks protect regionally important biodiversity. Two rare natural communities are known to occur in HTLN parks. The prairie on the Sioux quartzite outcrop at PIPE is classified as a Northern tallgrass quartzite-granite rock outcrop (Faber-Langendoen 2001) and may be "vulnerable-at moderate risk of extinction due to restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors" (Natureserve 2004). The Western Tallgrass Mesic Bur Oak Woodland (classification follows Faber-Langendoen 2001) at HOME is ranked as a very rare community at high to very high risk of extinction due to extreme rarity, steep declines, or other factors (Natureserve 2004). Ozark streams are biogeographically unique centers of endemism for a number of amphibian, fish, aquatic invertebrate, and cave-dwelling species. As urbanization and agriculture fragment Midwestern landscapes, the aquatic and terrestrial habitats in parks provide increasingly important refugia for numerous plants, animals, and natural communities. These habitats may support over 300 federally and state rare species that either historically inhabited, currently inhabit, or potentially inhabit network parks (Appendix 5).

Significant Stressors and Resource Management Concerns

HTLN differentiates stressors and resource concerns by the specificity of factors impacting natural resources. "Stressors" are anthropogenic factors outside the range of disturbances naturally experienced by the ecosystem (Whitford 2002). "Resource management concerns" result from multiple factors that have similar or cumulative effects on a resource or describe undesirable changes that result from unknown factors. Significant stressors and resource management concerns are based on: 1) relevance to park mission, 2) extent or magnitude of adverse impacts to natural resources, 3) potential duration of effects, and 4) immediacy of threat. Significant stressors and resource concerns were identified from management documents and communication with park resource managers (Table 1-6).

Table 1-6. Summary of significant stressors and resource management concerns for Heartland I&M Network and Prairie Cluster Prototype Monitoring Program parks

	ARPO	BUFF	CUVA	EFMO	GWCA	HEHO	HOCU	HOME	HOSP	LIBO	OZAR	PERI	PIPE	TAPR	WICR
Invasive Exotic Species															
plants	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
vertebrates	X	X				X				X					
invertebrates		X			X						X				
Adjacent Uses															
land use	X	X		X		X		X	X	X	X	X	X		X
water use/flow regime	X	X		X		X		X	X		X	X	X		X
air use										X					
Fire Exclusion		X			X	X		X		X	X	X	X	X	X
Unnatural Grazing														X	
Unnatural Browsing	X		X			X						X			X
In-Park Uses															
conflicting resource mgmt.												X			
visitor use		X	X								X		X		
erosion	X	X	X	X		X			X		X				
aquatic pollution		X	X	X		X	X		X		X		X		X
fragmentation			X												
Tree Disease									X						
Nuisance Wildlife	X		X				X								
Hazards															
flooding				X											
tick-borne disease	X														

Vital Signs Monitoring Goals and Objectives

HTLN Programmatic Goals and Tenets

NPS-wide Goals

The NPS-wide I&M Program has developed the following long-term goals to comply with legal requirements, fully implement NPS policy, and provide park managers with the data required to understand and manage park resources:

1. Determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.
2. Provide early warning of abnormal conditions and impairment of selected resources to help develop effective mitigation measures and reduce costs of management.
3. Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.
4. Provide data to meet certain legal and congressional mandates related to natural resource protection and visitor enjoyment.
5. Provide a means of measuring progress towards performance goals.

By adopting the NPS-wide monitoring goals, certain aspects of the HTLN program scope and direction become apparent. The program will include effects-oriented monitoring to detect changes in the status or condition of selected resources, stress-oriented monitoring to meet certain legal mandates (e.g. Clean Water Act), and effectiveness monitoring to measure progress toward meeting performance goals (Noon et al. 1999, National Research Council 1995). The NPS-wide goals also acknowledge the importance of understanding inherent ecosystem variability in order to interpret human-caused change and recognize the potential role of NPS ecosystems as reference sites for more impaired systems.

Network Tenets

In addition to the NPS-wide goals, HTLN has defined network-specific tenets as desired program characteristics and monitoring outcomes.

Desired Monitoring Program Characteristics:

1. The HTLN will achieve efficiency in monitoring to the extent possible by sharing resources.
2. Every park in the HTLN will have their highest priority monitoring requirements addressed in the process of developing the monitoring plan.
3. All aspects of the HTLN monitoring program will be guided by sound scientific principles.
4. The HTLN will build a foundation to institutionalize long-term monitoring within parks.

Desired Monitoring Outcomes:

1. HTLN monitoring priorities will be commensurate with the complexity of parks' issues and significance of parks' resources as determined by enabling legislation, strategic planning objectives, and regional and national conservation significance.
2. To achieve economies of scale, common monitoring themes will be derived from the top park priorities to the extent possible.
3. Park-specific priorities not covered by a common theme will also be addressed.
4. Objective and scientifically credible information will be provided to the parks in a timely way so the information can be used in management decisions.
5. Partnerships will be developed to leverage monitoring resources and to place the monitoring results within a regional context.
6. Periodic assessment/review will be implemented to assure monitoring is still addressing top park priorities.
7. The network will maintain flexibility to respond to episodic or catastrophic events.
8. Where possible, monitoring will address issues of public concern.
9. Information about the HTLN program and generated from monitoring activities will be shared with the public through media such as web pages, meetings, presentations, and posters in the parks.

Monitoring Objectives and Questions

The monitoring objectives describe the larger scientific questions that vital signs monitoring will attempt to answer for network parks. The HTLN monitoring objectives are grouped into three major categories: freshwater ecosystems, terrestrial ecosystems, and unbounded. Vital signs monitoring will directly address the monitoring questions listed under each monitoring objective.

Freshwater Ecosystems

Objective 1: **Understand the ecological relationships and long-term changes in the physical, chemical, and biotic components of streams and rivers.**

- How do water chemistry and biotic integrity change over time and in relation to habitat characteristics, stream conditions, and land use at local to watershed scales?
- Are water quality standards met for human uses such as drinking, swimming, and fishing?
- How are the abundance and distribution of animal populations (rare, keystone, pest) and/or communities changing over time and in relation to stream habitat, water quality, and land use at local to watershed scales?
- How does spring discharge affect the chemical and physical properties of water, fish, and invertebrate communities in rivers and streams?

Objective 2: **Understand the relationships between vegetation, soils, hydrology, landscape position, ecosystem functions, and biota in wetlands.**

- How do wetland vegetation, soils, and hydrological characteristics vary over space and time in relation to each other and to landscape position/surrounding land use?
- Which vegetation, soil, and hydrological variables are reliable indicators of high wetland quality (low eutrophication, relatively undisturbed hydrological regime, natural vegetation composition and structure) and important wetland functions (water storage capacity, flood control, important habitat, nutrient retention capacity, groundwater recharge, discharge to surface water)?
- How are the distribution and abundance of animal populations (rare, keystone, pest) and communities changing over time and in relation to wetland habitat characteristics, water quality, and land use?
- How are the abundance and distribution of invasive non-native wetland plants changing over time and in relation to wetland habitat characteristics, water quality, and land use?

Terrestrial Ecosystems

Objective 1: **Understand how environmental factors, ecosystem processes, land use, and resource management affect terrestrial vegetation, including rare or exemplary natural communities and outstanding habitats.**

- How is prairie composition and structure changing over time and in relation to fire and cattle grazing (where applicable)?
- How is woodland composition and structure changing over time and in relation to fire, gap formation, and deer browsing?
- How are fuel loads from live and dead vegetation changing over time and in relation to gap formation and fire?
- How are the abundance and distribution of invasive non-native plants changing over time and in relation to fire, grazing, land use, and vegetation management?
- How are the abundance and distribution of rare plant populations changing over time and in relation to weather, habitat characteristics, fire, competition, and trampling?

Objective 2: **Understand how animal populations and communities respond to changes in environmental factors, habitat characteristics, land use, and habitat management.**

- How are the abundance and distribution of animal populations (rare, keystone, pest) changing over time and in relation to habitat characteristics, land use, and human visitation?
- How are the abundance and distribution of animal communities changing over time and in relation to habitat and land use?

Unbounded

Objective 1: Understand how climate variation across the Midwestern U.S. affects network parks.

- How do climatic factors affecting plant and animal populations, communities, and aquatic systems vary seasonally and annually?
- What is the frequency and severity of extreme weather events (e.g. tornadoes, straight-line winds, microbursts, drought) that serve as important determinants of plant and animal community structure and composition.

Objective 2: Understand how variation in air quality across the Midwestern U.S. affects network parks.

- Are nutrient inputs from atmospheric deposition changing patterns of nutrient cycling?

- Do air quality variables exceed levels known to negatively affect plant and/or animal populations?

CHAPTER 2: CONCEPTUAL MODELS

Justification for Conceptual Models (from Thomas et al. 2003, Miller et al. 2003)

Conceptual models are "caricatures of nature" (Holling et al. 2002), designed to describe and communicate ideas about how nature works. Given the complexity of natural systems and the range of factors that influence natural processes, models provide a way to organize information. Conceptual models depicting key structural components and system drivers assist us in thinking about the context and scope of the processes affecting ecological integrity (Karr 1991).

They also provide a heuristic device to expand our consideration across traditional disciplinary boundaries (Allen and Hoekstra 1992). Learning that accompanies the design, construction, and revision of models contributes to developing a shared perspective of system dynamics and our current level of understanding (Wright 2002).

At all stages in the development of a monitoring program, conceptual models can improve communication between scientists from different disciplines, between scientists and managers, and between managers and the general public. Conceptual models should be used throughout the process of developing and implementing ecological monitoring.

One difficulty in building models is determining which system components and interactions to include. Starfield et al. (1994) advises thinking of a conceptual model as a 'purposeful representation of reality', rather than as a comprehensive one. Allen and Hoekstra (1992) emphasize that "we do not wish to show that everything is connected, but rather to show which minimal number of measureable connections may be used as a surrogate for the whole system in a predictive model." Too much information can obscure critical components, while too little may lead to oversimplification (Margoluis and Salafsky 1998).

Another important step in model construction is to identify an appropriate level of resolution, given the model objectives (Starfield and Bleloch 1986). Processes that occur much more slowly than the system of interest may be aggregated and considered as constraints of the system; processes that occur more rapidly may be aggregated and considered as 'noise' (Turner and O'Neill 1995).

Overview of Conceptual Models

General Conceptual Models for HTLN Parks

Two general conceptual models (Figures 2-1 and 2-2) provide the groundwork for seven specific conceptual models. The abstract nature of the general conceptual models serves two purposes: identifies the drivers, stressors, attributes, and measurements that are likely to be important based on the significant natural resources and significant stressors that were identified in Chapter 1, and shows the similarities that the seven individual models hold in common. Because of the numerous potential interactions among drivers and stressors, ecological effects are only included in the ecosystem-specific conceptual models.

These ecological effects are the source of the majority of resource management concerns in HTLN parks. Resource management actions attempt to prevent, mitigate, or reverse any negative effects on park resources.

Attributes that indicate changes in the severity, duration, or frequency of a stressor (i.e., the severity of the ecological effects) may be measured directly(e.g., water quality, exotic species locations), or by assessing their relative effect on plant and animal physiology, habitats, populations, or communities.

The general aquatic conceptual model supports the development of the Ozark Plateau river conceptual model (Supplemental Documents 16 and 17), the Midwestern stream conceptual model (Supplemental Document 18), and the prairie stream conceptual model (Supplemental Document 19). The general terrestrial conceptual model supports the development of the forest conceptual model (Supplemental Document 20) and the prairie conceptual model (Supplemental Document 21). The two general conceptual models in concert support the development of the Midwestern wetland conceptual model (Supplemental Document 22) and the land use change conceptual model (Supplemental Document 23).

The aquatic model also applies to forests subject to flooding as described in the forest conceptual model. While the general conceptual models and the specific conceptual models show a number of similarities, the narrative accompanying specific models describe the unique characteristics of the respective ecosystems.

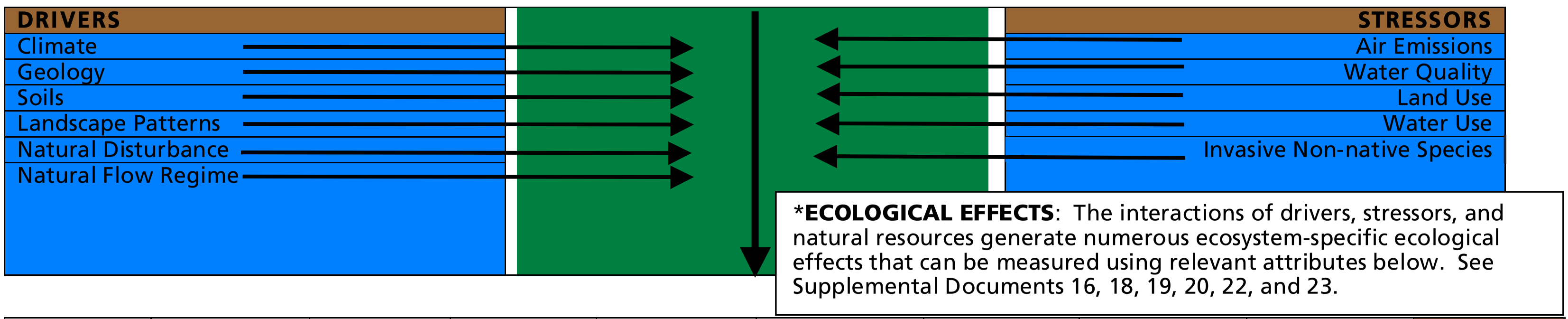
Conceptual Ecological Models for HTLN Parks

The conceptual models developed for the HTLN include stressor models and control models. Stressor models are designed to show the effect of anthropogenic stressors on natural resources, ecosystem processes, and vital signs (National Park Service (NPS) 2004b). The symbols for stressor models are shown in Table 2-1. Control models highlight “controls, feedback, and interactions responsible for system dynamics” (NPS 2004b).

The forest conceptual model applies to all parks with forest or woodlands. The Ozark Plateau stream conceptual model describes aquatic ecosystems at BUFF, GWCA, HOSP, OZAR, PERI, and WICR. The Midwestern stream conceptual model applies to river and streams at CUVA, EFMO, HEHO, and HOCU.

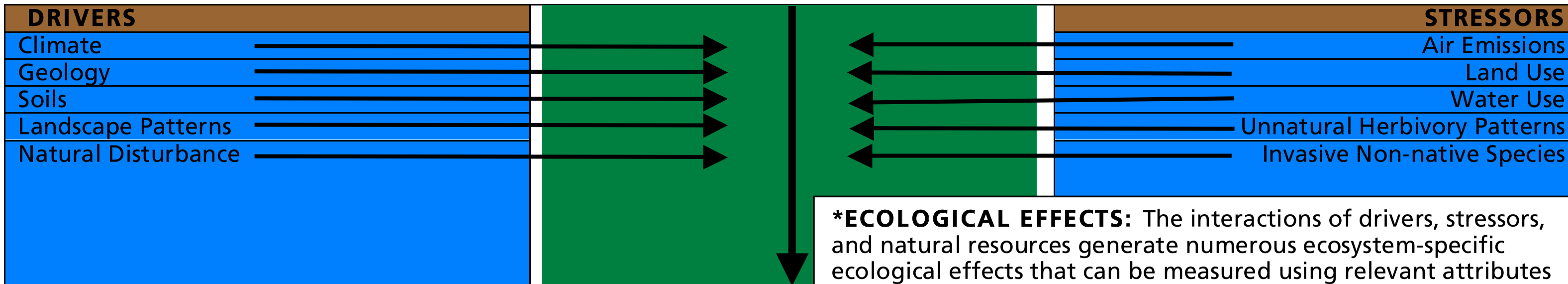
The Prairie conceptual model applies to EFMO, GWCA, HEHO, HOME, PIPE, TAPR, and WICR. The Prairie Stream conceptual model is designed for HOME, PIPE, and TAPR. Finally, the land use change conceptual model is relevant for all HTLN parks.

Figure 2-1. General aquatic conceptual ecological model for Heartland I&M Network and Prairie Cluster Prototype Monitoring Program



Hydrology	Water Chemistry	Air Chemistry	Weather	Energy Flow	Faunal Characteristics	Landscape	Vegetation Characteristics	Streambed Characteristics	ATTRIBUTES
-Water removal -Current -Discharge -Recharge -Runoff -Flooding -Subsurface flow -PFC? -Temperature -Flow patterns -Water budget -Sediment load	-Cations/Anions -Core-5 -BOD/COD -Dissolved oxygen -Chlorophyll a -Dissolved organic matter -Pathogens -Toxins -Heavy metals -Nutrients -Turbidity -Chloride -Alkalinity	-Emissions -Wet fall -Dry fall -Ozone	-Precipitation -Temperature -Evaporation -Severe weather -Drought	-Decomposition -Nitrification -Primary production -Allochthonous input -P/R ratio -Nutrient cycling	(esp. zooplankton, fish, invertebrates) -Species composition -Abundance -Population dynamics -Species richness -Species diversity -Guild diversity -Habitat condition -Harvest mortality -Bioindices -Toxin concentrations -Disease incidence	-Urbanization -Agriculture -Logging -Mining -BMPs -Land cover -Hillside cutting -Canalization -Connectivity -Zoning -Demographics	(esp. periphyton, phytoplankton, algal beds, macrophytes, riparian vegetation) -Composition -Density -Cover -Frequency -Biomass -Population dynamics -Species richness -Species diversity -Structure -Guild diversity -Transpiration -Community type	-Floodplain/ wetland filling -Crossection profiles -Riparian condition -Aggradation -Degradation -Morphology -Connectivity -Heterogeneity -Substrate type -Substrate size -Impervious surface -Embeddedness	MEASUREMENTS

Figure 2-2. General terrestrial conceptual ecological model for Heartland I&M Network and Prairie Cluster Prototype Monitoring Program



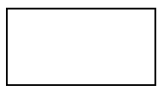
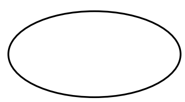
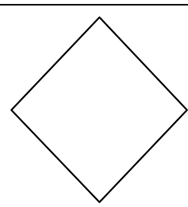
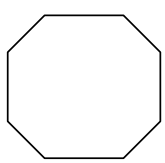
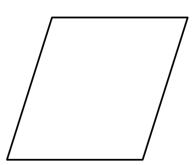
***ECOLOGICAL EFFECTS:** The interactions of drivers, stressors, and natural resources generate numerous ecosystem-specific ecological effects that can be measured using relevant attributes below. See Supplemental Documents 20, 21, and 23.

Soils	Air Chemistry	Weather	Energy Flow	Faunal Characteristics	Landscape	Vegetation Characteristics	Disturbance Regime	ATTRIBUTES
-pH -organic matter -Cation exchange capacity -Erosion -N, P, K, S -Bulk density -Water -Stratification -Structure -Texture -Invertebrates -Toxins -Mycorrhizae	-Emissions -Wet fall -Dry fall -Ozone	-Precipitation -Temperature -Evaporation -Severe weather -Drought	-Decomposition -Nitrification -Primary production -Allochthonous input -P/R ratio -Nutrient cycling	-Species composition -Abundance -Population dynamics -Species richness -Species diversity -Guild diversity -Habitat condition -Harvest mortality -Bioindices -Toxin concentrations -Disease incidence	-Urbanization -Agriculture -Logging -Mining -BMPs -Land cover -Hillside cutting -Canalization -Connectivity -Zoning -Demographics	-Composition -Density -Cover -Frequency -Biomass -Population dynamics -Species richness -Species diversity -Structure -Guild diversity -Transpiration -Community type -Photosynthesis -Growth -Tissue injury -Disease incidence	-Fire frequency, severity, extent -Fuel loads -Grazing -Browsing -Gap formation -Gap size, frequency, distribution -Soil disturbance frequency, severity, extent	MEASUREMENTS

Conceptual Model Definitions and Symbols (Route et al. 2004)

HTLN adopted a standardized terminology for describing and diagramming conceptual models (NPS 2004c).

Table 2-1. Symbols used in conceptual ecological models

	Symbol	Description
Drivers		*Drivers* can be either anthropogenic or naturally occurring and are major forces of change. Examples include human development, climate, fire cycles, hydrologic cycles, and natural disturbance events (e.g., droughts, floods, lightning-caused fires) that have large-scale influences on the attributes of natural systems.
Stressors		*Stressors* are physical, chemical, or biological perturbations to a system that are either foreign to that system or natural to the system but occur at an excessive or deficient level. Stressors cause significant changes in the ecological components, patterns, and processes in natural systems. Examples include air pollution, water pollution, water withdrawal, pesticide use, timber and game harvest, and land-use change. Stressors act together with drivers on ecosystem attributes.
Ecological Effects		*Ecological effects* are the physical, chemical, biological, or functional responses of ecosystem attributes to drivers and stressors.
Attributes		*Attributes* are any living or nonliving environmental feature or process that can be measured or estimated to provide insights into the state of the ecosystem. The term *indicator* is reserved for a subset of attributes that is particularly information-rich in the sense that their measures are indicative of the quality, health, or integrity of the larger ecological system. Indicators are a selected subset of the physical, chemical, and biological elements and processes of natural systems selected to represent overall health or condition of the system, known or hypothesized effects of stressors, or elements having important human values. *Attributes* are good *vital sign* candidates.
Measurements		*Measures* are the specific variables used to quantify the condition or state of an attribute or indicator. These are specified in sampling protocols. For example, stream acidity may be the indicator, but pH units are the measure.

Examples of Conceptual Models for HTLN Parks

Midwestern Wetland Model

The Midwestern wetland conceptual model, a stressor model, characterizes wetlands on HTLN parks (Figure 2-3). The model demonstrates how stressors affect ecosystem function and consequently important natural resources. For example, a recent study at CUVA identified the most reliable indicators of wetland function. The conceptual model will facilitate the interpretation of these indicators within the CUVA landscape, which has a long history of agricultural and industrial disturbance.

Terrestrial Prairie Conceptual Model

The Prairie Cluster Prototype Long Term Ecological Monitoring Program developed the terrestrial prairie conceptual model prior to the formation of HTLN (Figure 2-4, Supplemental Documents 21). The model includes stressors, drivers, ecological effects, and attributes, but also makes a greater effort to include interactions within the system. The arrows also implicitly include ecological effects, demonstrating how changes in one system component affect connected components.

Conceptual Models and Vital Signs Selection

Prior to vital signs selection, a list of candidate vital signs was developed from several sources, including conceptual models. HTLN staff evaluated attributes in conceptual models and linked those attributes with vital signs generated in planning meetings. Conceptual models were designed to highlight the ecological interactions, ecosystem processes, and stressors that act on significant natural resources or generate significant natural resource concerns. The forest conceptual model provides an example of how conceptual models generate candidate vital signs (Figure 2-5). Red hexagons encapsulate attributes and vital signs. The attributes from the original forest conceptual model are denoted with blue text. The candidate vital signs that were derived from those attributes are shown in red text.

Figure 2-3. Midwestern wetland conceptual model

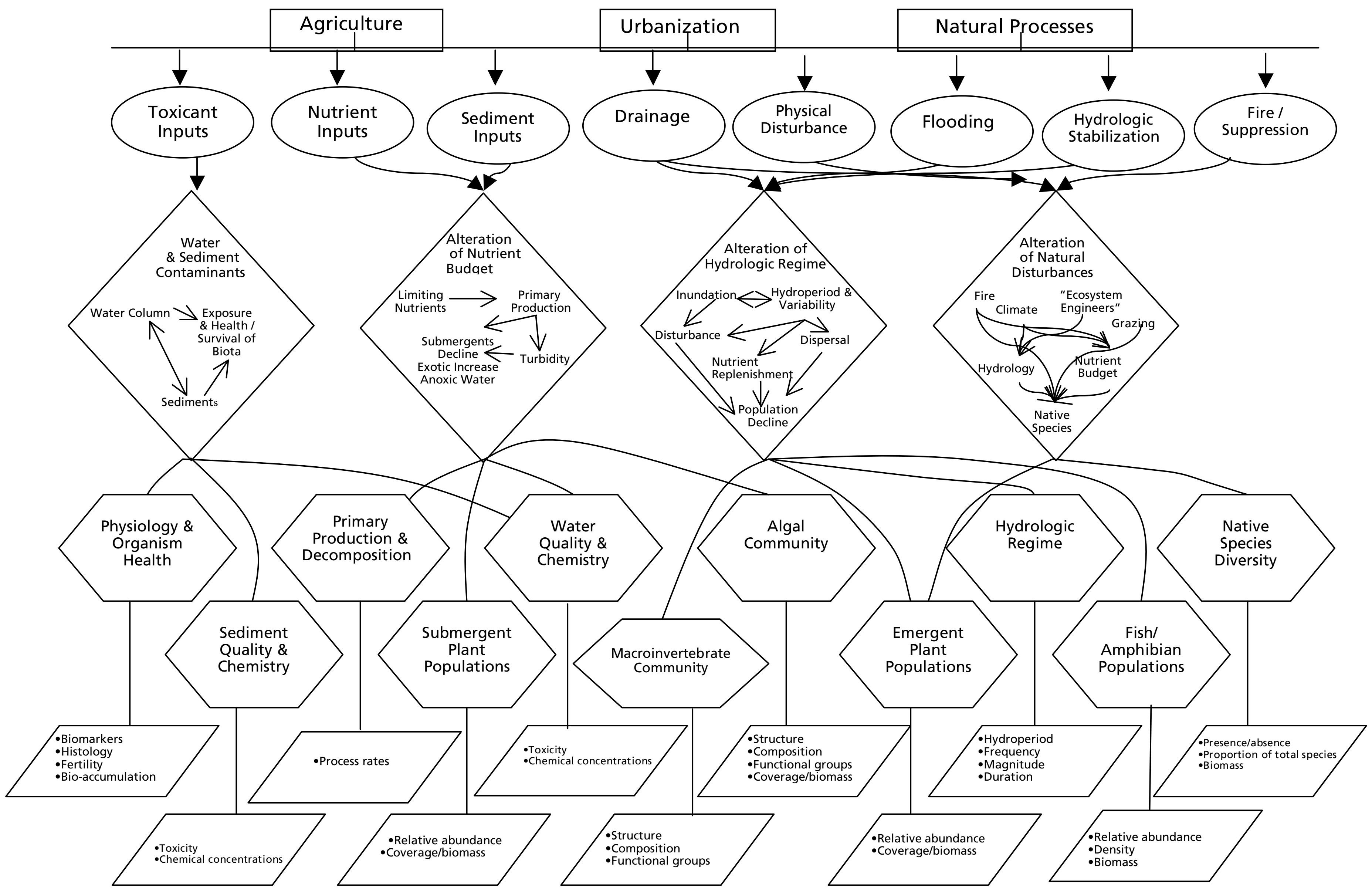


Figure 2-4. Relationships between anthropogenic stressors and core abiotic and biotic components affecting terrestrial prairie ecosystems. *Modified from Hartnett and Fay (1998)*

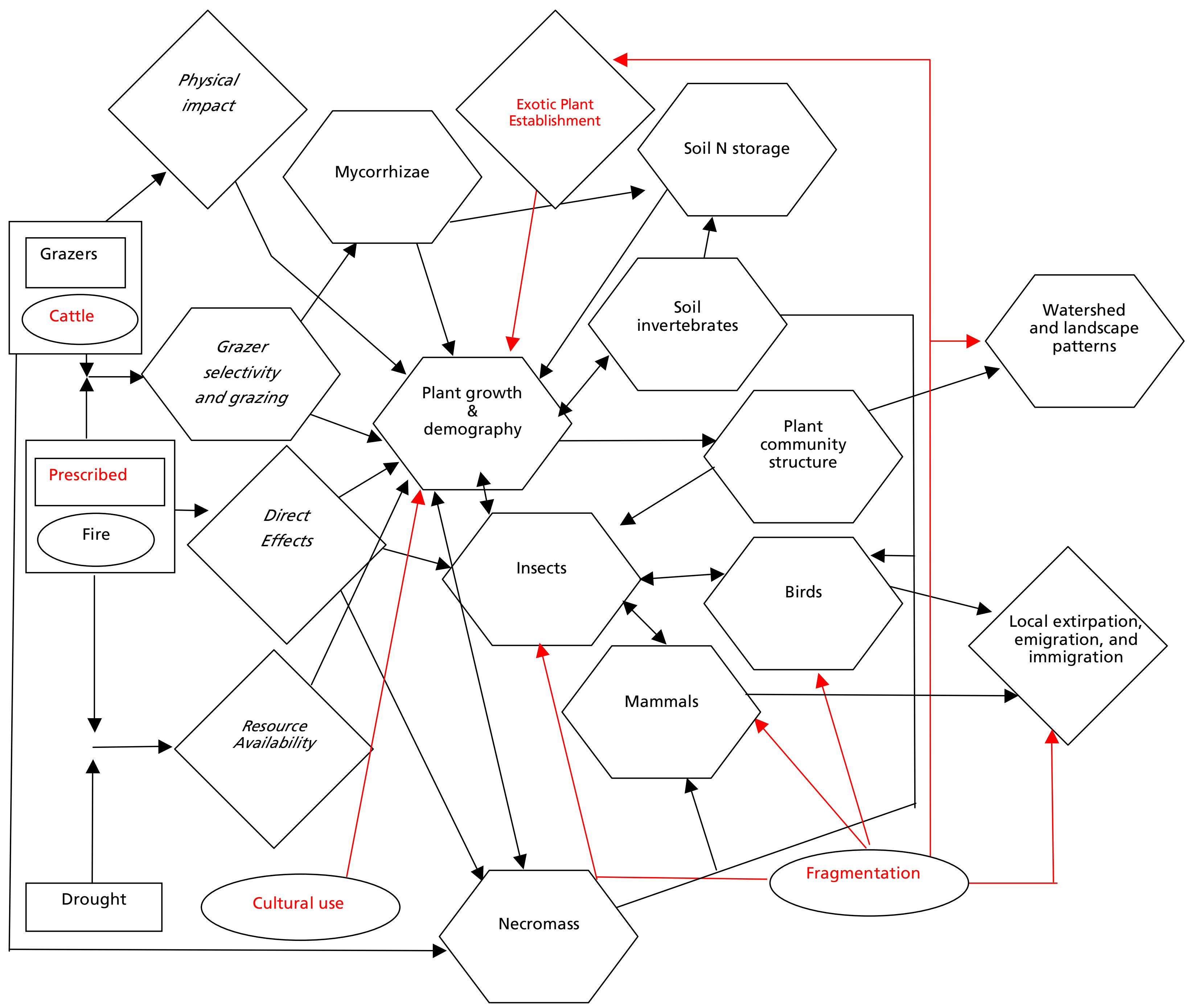
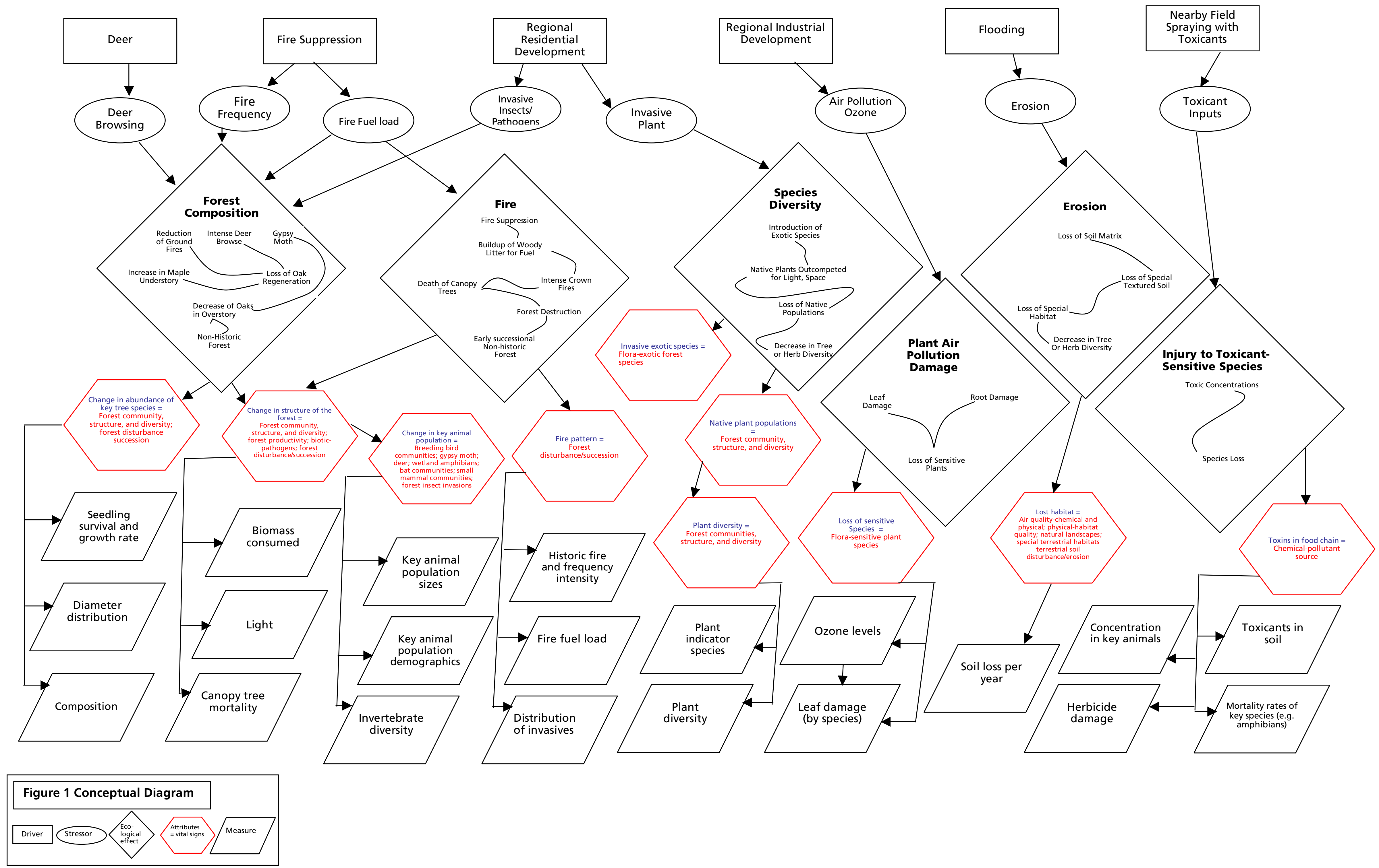


Figure 2-5. Forest ecosystem conceptual model demonstrating relationships between attributes and vital signs



CHAPTER 3: VITAL SIGNS

Process for Evaluating, Prioritizing, and Selecting Vital Signs

Network staff assembled a list of candidate vital signs from several sources. The attributes in conceptual models (Chapter 2) were linked with vital signs generated in planning meetings and documents (Supplemental Documents 2 through 8). Through meetings and interviews, park resource managers and subject matter experts introduced candidate vital signs, including park-specific vital signs. The complete list of 82 candidate vital signs is presented in the vital signs selection database (Supplemental Documents 24 and 25, Appendix 6).

Because HTLN funding is insufficient to monitor all of the candidate vital signs, the network was required to prioritize the list. To accomplish this task, HTLN held a vital signs selection meeting in St. Louis, Missouri in July 2003. At this meeting, HTLN superintendents, natural resource managers, and network staff prioritized the list of candidate vital signs to select the most critical indicators. The HTLN prioritization process (Figure 3-1) included: (1) development and endorsement of the indicator ranking criteria by the technical committee prior to the workshop, (2) design of an automated database system to facilitate the ranking process, (3) population of the database with park-specific vital signs lists and justifications, (4) participant review of the park-specific vital signs lists and recommendations for additions or deletions, (5) scoring of each vital sign, (6) presentation of the ranked vital signs lists, and (7) review of the lists for significant vital signs specific to only one or two parks. These steps are described in detail in Appendix 7.

Implementation Strategy for Vital Signs Monitoring

A final list of vital signs was derived from prioritization analyses (Appendix 8), consideration of ongoing monitoring efforts, and opportunities to leverage network funds through partnerships (Table 3-1). The number of vital signs included in the final list, as well as their patchwork implementation across parks, reflects the diversity of natural resources and resource management concerns within the network. Given the long list of vital signs, a staggered implementation plan is required. By focusing initial design efforts on network-wide tier 1 vitals signs, the network maximizes short-term returns. Once monitoring is operational for tier 1 vital signs, design attention will shift to park-specific tier 2 vital signs.

Monitoring of Impaired and Pristine Waters

Funds from the NPS Water Resources Division to HTLN are designated towards the monitoring of impaired and pristine waters in the network. For streams and rivers classified as impaired under section 303(d) of the Clean Water Act, we did not consider individual contaminants as vital signs. Nonetheless, HTLN has several planned or ongoing projects focusing on impaired waterways (Supplemental Document 26). In general, the projects involve working with state and USGS partners to develop total maximum daily loads (TMDL), or monitor for compliance to TMDL following management actions. In other cases, HTLN efforts are focused on acquiring and summarizing data collected by other entities, particularly the state regulatory agencies.

The Buffalo River, Jacks Fork, and Current Rivers are also designated as pristine waters. As described in more detail in chapters four and five, HTLN intends to monitor a suite of variables at BUFF and OZAR to describe the biological, physical, and chemical properties of these rivers. Monitoring will quantify desired levels of water quality and provide early warning of emerging water quality problems.

Figure 3-1. Detailed flow-chart of work plan to select monitoring vital signs (Thomas et al. 2003 with minor modification)

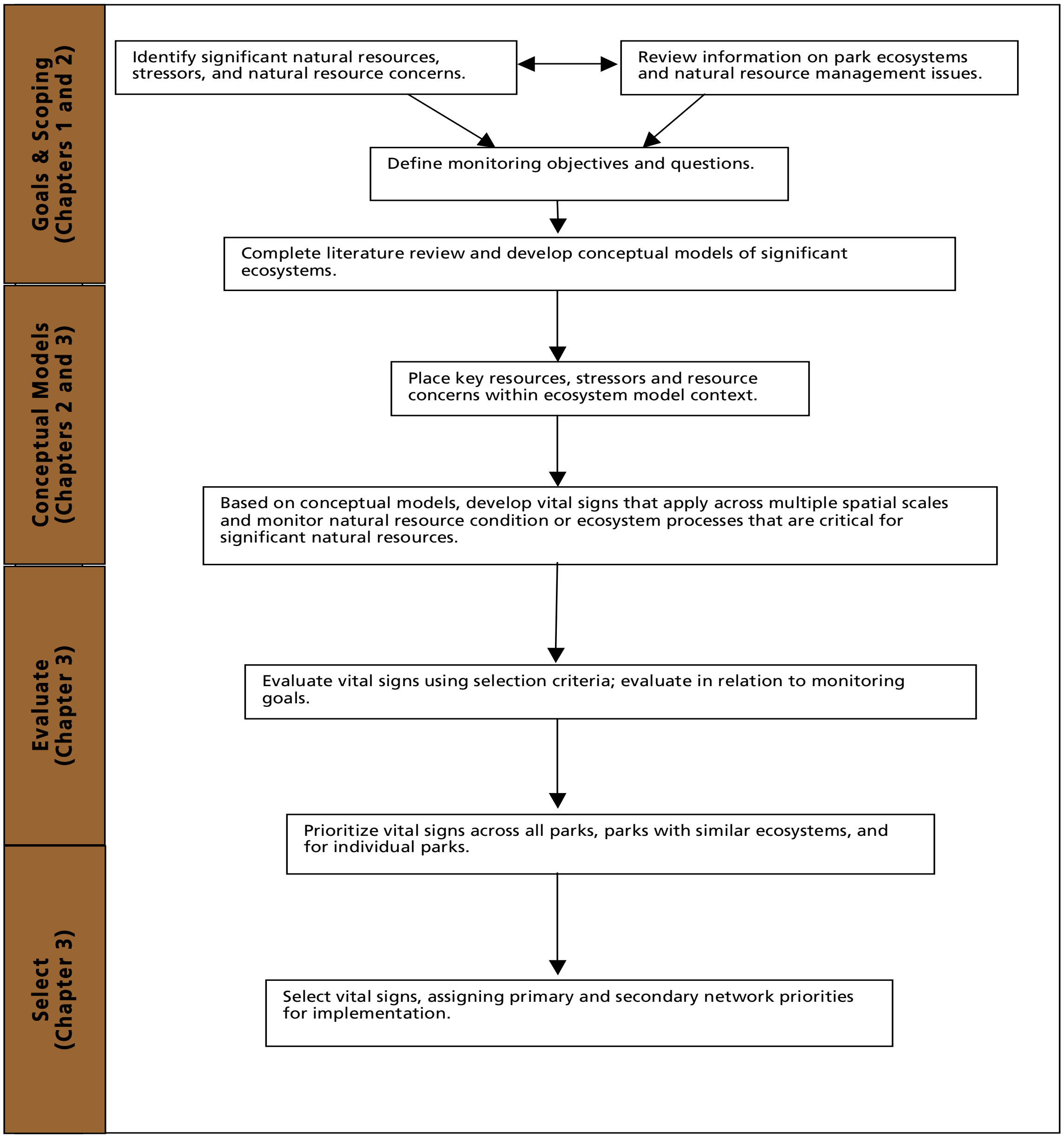


Table 3-1. List of vital signs selected for implementation in Heartland I&M Network and Prairie Cluster Prototype Monitoring Program parks

Level 1	Level 2	Level 3	Network Vital Sign Name[1]	ARPO	BUFF	CUVA	EFMO	GWCA	HEHO	HOCU	HOME	HOSP	LIBO	OZAR	PERI	PIPE	TAPR	WICR
Air and Climate	Air Quality	Ozone	Ozone	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
		Wet and Dry Deposition	Wet and Dry Deposition	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
		Visibility and Particulate Matter	Visibility and Particulate Matter	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
	Weather and Climate	Weather and Climate	Weather	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
Geology And Soils	Geomorphology	Stream/ River Channel Characteristics	Fluvial Geomorphology		X									X				
			Stream Habitat/ Riparian Assessment					X	*		X					X	*	X
Water	Hydrology	Groundwater Dynamics	Spring Discharge									#		*				
		Surface Water Dynamics	Stream Discharge	#	#	#	#	#	#	#	#	#		#	#	#	#	#
	Water Quality	Water Chemistry	Core Water Quality Parameters		X	#	#	X	#		X			X		X	X	X
			Drinking Water Quality									#						
		Nutrient Dynamics	Nutrient Loading		#	#	#							#		#		#
		Toxics	Pathogens		#	#	#							#		#		#
			Pollutant Metals			#								X				
		Aquatic Invertebrates and Algae	Aquatic Invertebrates—Prairie Streams					X	*		X					X	*	X
			Aquatic Invertebrates—Rivers		X	#								X				
Biological Integrity	Invasive Species	Invasive/Exotic Plants	Exotic Forest Plants	X		X	X	X		X	X	X	X		X	X	X	X
		Invasive/Exotic Plants	Exotic Grassland Plants					X	X	X						X	X	X
		Invasive/Exotic Animals	Nutria	*														
	Infestations and Disease	Insect Pests	Gypsy Moths			*				*			*					
	Focal Species or Communities	Wetland Communities	Wetland Plant Communities			X												
		Grassland Communities	Prairie Community Structure, Composition, and Diversity				X	X	X		X					X	X	X
Biological Integrity	Focal Species or Communities	Forest Vegetation	Forest Community Structure, Composition, and Diversity	X			X			X	X	X	X		X			X
		Fishes	Fish Community—Prairie Streams													X	X	
			Fish Community—Ozark Rivers		X									X				
		Birds	Landbirds	X					X	X							X	
		Mammals	Deer	X		#							X		X			X
			Gray Bat		*									*				*
			Indiana Bat		*	*								*				
			Ozark Big-Eared Bat		*													
	At-risk Biota	Threatened and Endangered Species and Communities	American Alligator	*														
			Missouri Bladderpod															X
			Ozark Hellbender											X				
			Topeka Shiner													X	X	
			Western Prairie Fringed Orchid													X		
Ecosystem Patterns and Processes	Land Cover and Use	Land Cover and Use	Land Cover/Land Use		X		X					X	X	X	X	X		X

[1]Protocols for monitoring blue vital signs are complete or in development.
X – Parks where the vital sign is scheduled for implementation in 2 to 4 years.
* - Parks where the vital sign is scheduled for implementation after four years and contingent on funding.
# - Vital sign monitored by a group other than HTLN.

CHAPTER 4: SAMPLING DESIGN

Introduction

The primary purpose of a sampling design is to ensure the data collected are representative of the target population(s), and sufficient to draw defensible conclusions about the resources of interest. In this chapter, we discuss how our sample design ensures the scientific merit of our program. We assume that the reader is familiar with basic principles of sample design; appendix 9 contains a discussion of these principles and an elaboration of the concepts presented in bold face. Here we describe, in a broad context, how these principles will be employed in sampling terrestrial and aquatic habitats of our network. The specific designs detailed in individual protocols follow from these basic themes and incorporate variations as necessary. These details can be found in the monitoring protocols for individual vital signs (Supplemental Documents in Chapter 5). Important aspects of our sample design for all vital signs are summarized in Table 4-1.

Terrestrial Systems

Sample Selection

In general, the sampling design for most terrestrial monitoring projects is based on a systematic grid in which all points, a systematic subset, or some random subset of the total may be sampled. This choice will ultimately depend upon park size, spacing between points, time required to sample each point, and available personnel. Location of sample points is determined by overlaying the area of interest with a two-dimensional grid. If **systematic sampling** is appropriate, then all or some systematic fraction of points are sampled. If not, then we randomly select some proportion of points to sample. If **stratification** is necessary, strata are defined before sites are determined. Regardless of the specific approach chosen (i.e., **systematic, random, stratified random**), the same underlying grid can be used at each park for different sampling protocols.

By sharing a common underlying grid, multiple protocols using different spatial allocation approaches can maximize **co-location** of sample sites. Figure 4-1 illustrates a hypothetical example of superimposing several different survey designs on a single systematic grid. First, a relatively fine scale grid (e.g., 100 x 100m) is superimposed on the **sample frame**. Vertices of the grid form a pool of potential sample points, and those falling outside the reference frame are removed from consideration. For example, the HTLN is developing rapid data collection methods for invasive plant species monitoring to maximize spatial coverage.

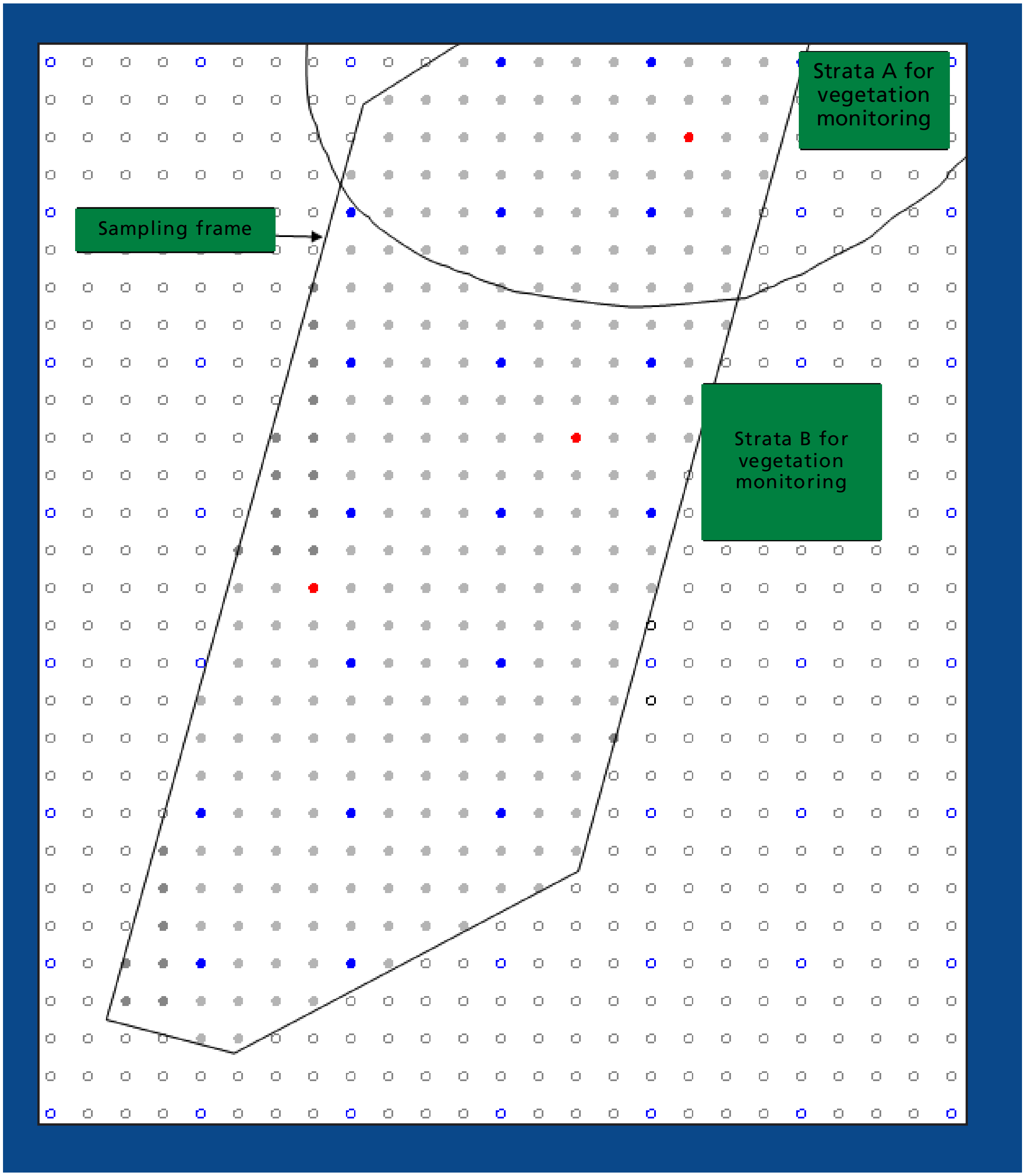
All sample points in the reference frame (i.e., all filled circles) would be utilized in a systematic sample.

Protocols for monitoring breeding birds utilize a systematic survey design at a larger spatial scale (400 x 400m). The initial grid would be subsampled to the desired scale as indicated by blue circles. Initially establishing a relatively fine-scale grid allows flexibility in scaling up to meet different design requirements. At points represented by solid blue dots, both invasive plant species and breeding bird monitoring would be co-located.

Table 4-1. The overall sample design approach, methods for spatially allocating samples, and revisit plan for vital signs monitoring

Level 1	Level 2	Level 3	Network Vital Sign Name	Overall Sample Design Approach	Spatial Allocation	Revisit Plan
Ecosystem Patterns and Processes	Land Cover and Use	Land Cover and Use	Land Cover/Land Use			
Air and Climate	Air Quality	Ozone	Ozone	NA	NA	Continuous
Air and Climate	Air Quality	Wet and Dry Deposition	Wet and Dry Deposition	NA	NA	Continuous
Air and Climate	Air Quality	Visibility and Particulate Matter	Visibility and Particulate Matter	NA	NA	Continuous
Air and Climate	Air Quality	Air Contaminants	Air Contaminants	NA	NA	Continuous
Air and Climate	Weather and Climate	Weather and Climate	Weather	NA	NA	Continuous
Geology and Soils	Geomorphology	Stream/ River Channel Characteristics	Fluvial Geomorphology	Aquatic – one dimensional	GRTS	[1-0,1-4]
Geology and Soils	Geomorphology	Stream/ River Channel Characteristics	Stream Habitat/ Riparian Assessment	Aquatic – one dimensional	GRTS	[2-5]
Geology and Soils	Geomorphology	Surface Water Dynamics	Stream Discharge	NA	NA	Continuous
Geology and Soils	Water Quality	Water Chemistry	Core Water Quality Parameters	Aquatic – one dimensional	Various	Various
Geology and Soils	Water Quality	Toxics	Pollutant Metals	Aquatic – one dimensional	GRTS	[1-0,1-4]
Geology and Soils	Water Quality	Aquatic Invertebrates and Algae	Aquatic Invertebrates—Prairie Streams	Aquatic – one dimensional	Exhaustive Sample	Annual
Geology and Soils	Water Quality	Aquatic Invertebrates and Algae	Aquatic Invertebrates—Rivers	Aquatic – one dimensional	GRTS	[1-0,1,4]
Biological Integrity	Invasive Species	Invasive/ Non-native Plants	Exotic Forest Plants	Terrestrial – two dimensional	Systematic	[1-5]
Biological Integrity	Invasive Species	Invasive/ Non-native Plants	Exotic Grassland Plants	Terrestrial – two dimensional	Systematic	[1-5]
Biological Integrity	Focal Species or Communities	Wetland Communities	Wetland Plant Communities	Terrestrial – two dimensional	TBD	TBD
Biological Integrity	Focal Species or Communities	Grassland Communities	Prairie Community Structure, Composition, and Diversity	Terrestrial – two dimensional	Stratified Random	[2-3]
Biological Integrity	Focal Species or Communities	Forest Vegetation	Forest Community Structure, Composition, and Diversity	Terrestrial – two dimensional	Stratified Random	[2-3]
Biological Integrity	Focal Species or Communities	Fishes	Fish Community—Prairie Streams	Aquatic – one dimensional	Exhaustive Sample	[1-0,1-4]
Biological Integrity	Focal Species or Communities	Fishes	Fish Community—Ozark Rivers	Aquatic – one dimensional	GRTS	[1-0,1-4]
Biological Integrity	Focal Species or Communities	Birds	Land birds	Terrestrial – two dimensional	Systematic	Annual
Biological Integrity	Focal Species or Communities	Mammals	Deer	Terrestrial – two dimensional	TBD	TBD
Biological Integrity	Focal Species or Communities	Threatened and Endangered Species and Communities	Missouri Bladderpod	Terrestrial – two dimensional	Adaptive Cluster Sampling	Annual
Biological Integrity	Focal Species or Communities	Threatened and Endangered Species and Communities	Ozark Hellbender	Aquatic – one dimensional	Dual Frame - GRTS	[1-0,1-2]
Biological Integrity	Focal Species or Communities	Threatened and Endangered Species and Communities	Topeka Shiner	Aquatic – one dimensional	NA – Population Census	Annual
Biological Integrity	Focal Species or Communities	Threatened and Endangered Species and Communities	Western Prairie Fringed Orchid	Terrestrial – two dimensional	NA – Population Census	Annual

Figure 4-1. A hypothetical example of superimposing, on a single underlying grid, several monitoring projects each using a different technique for selecting sample locations. In this example, invasive plant monitoring would utilize a systematic sample from a fine scale grid (all solid dots). Breeding bird monitoring would utilize a systematic sample from a coarser scale grid (solid blue dots). Vegetation community monitoring would draw a relatively small stratified random sample from the pool of potential sites (solid red dots).



Finally, vegetation community monitoring methods are intensive and time consuming; therefore, total sample sizes must remain small. Given relatively small sample sizes and the desire to capture heterogeneity in vegetation communities that reflects underlying differences in soil type and aspect, a stratified random sample is drawn. In this example, the three sample sites are drawn at random from strata A and B with the number of sites per strata proportionate to the area of the strata, thus creating equal probability for selection. At points represented by solid red dots, both invasive plant species and vegetation community monitoring are co-located.

In addition to the general approach described above (e.g., systematic, stratified random), the HTLN is also utilizing adaptive **cluster sampling** and complete census techniques in monitoring rare plant populations (Table 4-1).

Panel Membership and Revisit Design

Panel membership and **revisit design** describe how sites at each park are sampled through time. As a demonstration of how the revisit design must accommodate a network-wide logistical plan, we continue the example from vegetation community monitoring. In general, vegetation community monitoring sites are sampled for two consecutive years followed by three years of no sampling (i.e., a [2 - 3] **rotating panel**; Table 4-2). This design is well suited for trampling-sensitive systems such as glades, tallgrass prairies, mixed grass prairies, and savannas; allows for a greater number of sites to be visited through time; and provides a three-year window in which to initiate management activities. Furthermore, sampling for two consecutive years statistically reduces the effect of annual variability on the detection of trends in plant communities that are temporally dynamic.

In two parks, more intensive monitoring is planned as part of ongoing research and design work. At Tallgrass Prairie National Preserve (TAPR), a **split panel** revisit plan has been employed in which a subset of sites is sampled annually, while other sites are rotated on a four year cycle [1 – 0, 1 – 3] (Table 4-3). The **always revisit** panel is well suited to detect gross change and components of individual change. A primary drawback of this design is the burden placed on core sites through trampling pressure related to annual sampling. At TAPR, however, sampling-related trampling issues are minimal compared to the intensive cattle grazing currently implemented. TAPR is the only park in the network able to sustain an annual sample because of the intensive grazing already occurring. The group of annually sampled sites is coupled with a second panel of sites from each pasture scheduled for monitoring on a four year rotation [1- 3]. The second panel provides a better estimate of status and improves our ability to compare plant communities among pastures under different management regimes.

At Effigy Mounds National Monument (EFMO), the plan for monitoring additional forest sites involves a rotating panel design [1 – 2]. All sample sites will be placed into three panels based on fire management units and tentatively sampled once every three years. Unlike TAPR, there is not an annually sampled panel at EFMO due to the sensitivity of the forest community to trampling.

Table 4-2. Network-wide logistical plan for rotating annual vegetation community monitoring effort among network parks. (Different vegetation communities are monitored at EFMO in the always revisit panel [forests] compared to the rotating panel [prairies])

Tour	Region (Parks)	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	Short-grass prairie tour (AGFO – SCBL)	X	X				X	X				X	X
2	Tallgrass prairie tour (HOME – PIPE)			X	X				X	X			
3	Deciduous forest tour (LIBO – HOCU - WICR)				X	X				X	X		
4	Ozarks tour (PERI – HOSP – ARPO)					X	X				X	X	
5	Prairie-savanna tour (EFMO – HEHO – GWCA)		X	X				X	X				X
6	Flint Hills tallgrass prairie tour (TAPR)	X	X	X	X	X	X	X	X	X	X	X	X
7	Eastern forest tour (EFMO)	X	X	X	X	X	X	X	X	X	X	X	X

In designing vital signs monitoring for multiple NPS units at the network scale, logistics may constrain the survey design at any particular park. For example, plant community monitoring is ongoing or scheduled for 14 parks dispersed widely across the Great Plains. We utilize sampling tours comprised of parks in geographic proximity to one another to achieve operational efficiency (Table 4-2, Figure 4-2). Every park in the tour is visited during a single trip (not to exceed 10 days). In most cases, all vegetation monitoring sites within a park are sampled during each visit. The tour concept ensures that parks in relatively close proximity of each other are sampled consecutively, thereby reducing time and travel-related expenses.

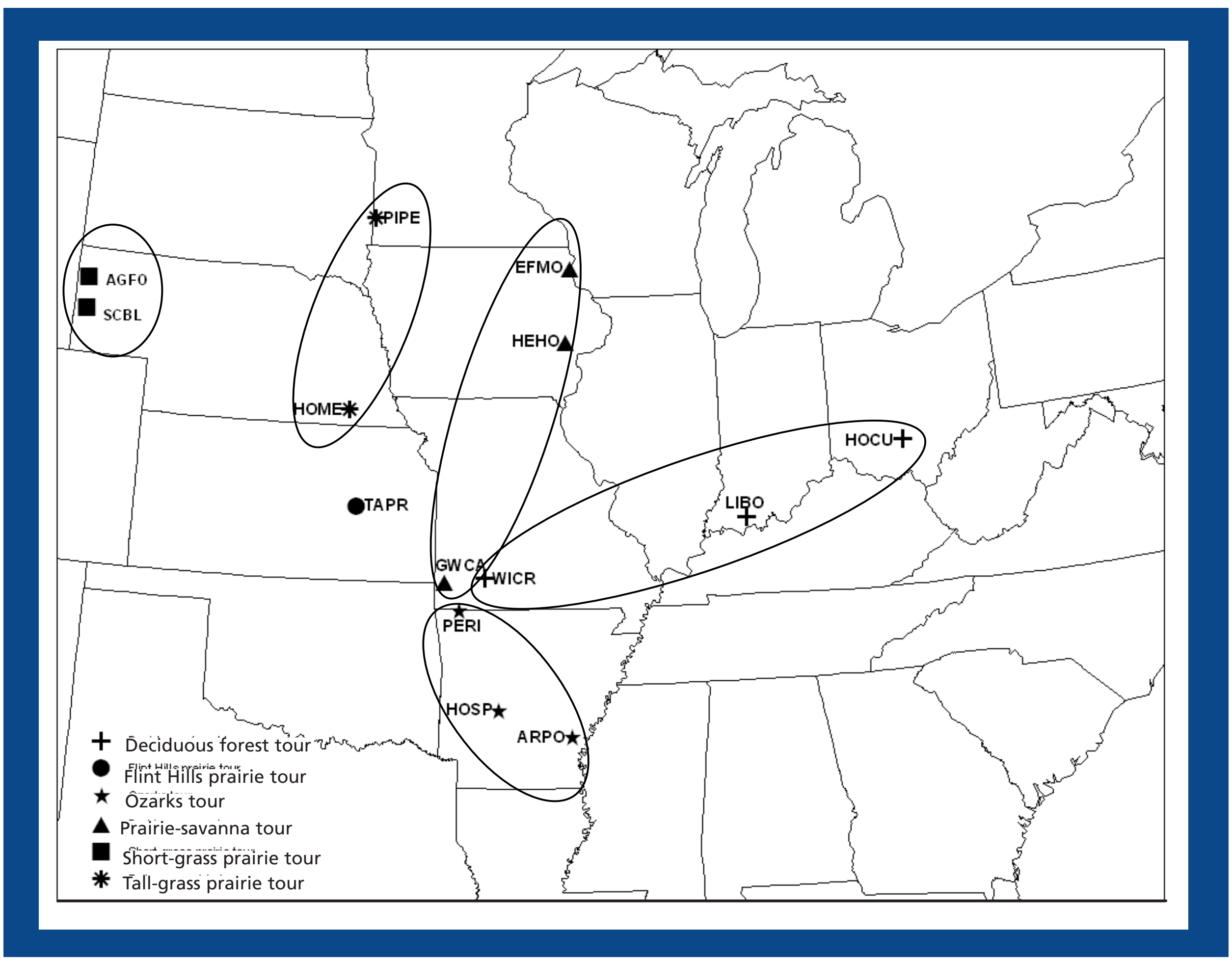
Table 4-3. Split panel revisit design for Tallgrass Prairie National Preserve [1 – 0, 1 – 3]

Sample Panels	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Core sites (n=18)	X	X	X	X	X	X	X	X	X	X	X	X	X
Crusher pasture (n=5)	X				X				X				X
Redhouse pasture (n=6)		X				X				X			
Windmill pasture (n=8)			X				X				X		
Gashouse pasture (n=11)				X				X				X	

In determining the logistical plan, the timing of sampling within the growing season was considered, as well as the maximum number of plots that could be revisited within a year. With sampling limited to early May through mid-October, selecting the optimal sequence of tours is crucial. Each community type has a unique sample time within the growing season that is optimal for capturing the diversity and complexity of the system. Plant communities are sampled at approximately the same time each year to remove seasonality from cover and frequency estimates. This minimizes difficulties in differentiating long-term trends from changes attributable to seasonal variability.

Unlike many large-scale environmental monitoring studies, region-wide inferences incorporating cross-tour analyses are not intended. In this case, the study units within the parks remain the framework for statistical interest. Results are not extrapolated to include all parks within a tour and trends will not be analyzed across tours.

Figure 4-2. Groups of parks, or tours, scheduled in a single vegetation community monitoring field trip. (TAPR and forests at EFMO are sampled every year; prairies at EFMO are sampled on a rotating basis.)



River Systems

River systems are linear and require a different approach than terrestrial habitats (See Supplement Document 27). Buffalo National River (BUFF) and Ozark National Scenic Riverways (OZAR) are two 'river' parks within the HTLN network. Preserving the aquatic resources of these parks is of primary importance, and the park boundaries closely parallel the rivers and important tributaries. Five major vital signs are proposed for evaluation under a unified monitoring design: Ozark hellbenders, fish communities, invertebrates, geomorphology, and heavy metals (primarily lead, but also nickel and cadmium). In order to maximize sampling efficiency and the amount of information available for each site, we will **co-locate** and **co-visit** as many sample sites as possible. Although we monitor aquatic resources in other parks in the HTLN network, here we focus on BUFF and OZAR because they represent relatively large river systems requiring substantial sampling efforts. Also, other aquatic resources are being sampled as part of the PC-LTEM program, and their sample design has already undergone a thorough review.

Sample Selection

We defined the sample unit to be the largest entity upon which one of the five study's field protocols could be applied. As a common sample unit definition, we will use a 'stretch' of contiguous river of some minimum and maximum length. Because the geomorphology of these waterways (and the resulting biological processes) are scale-dependent, different categories of stretch sizes will be employed. For example, as rivers become wider, the distance separating riffles increases. The protocol for sampling macroinvertebrates requires sampling three riffles, so this protocol will require longer sections in the main stems than in the tributaries. In the tributaries and upper main stems, stretch lengths of 1-3 km may be adequate. The middle and lower main stems may require stretch lengths of 3-5 km to accommodate all studies. A key characteristic of the overall design is that all studies are capable of producing unbiased estimates that are applicable to the entire stretch. While stretches must be long enough to accommodate unbiased estimates for all studies, they do not have to be the same size. Once defined, sample unit boundaries will remain fixed forever and be used by all studies under the unified monitoring design.

For both BUFF and OZAR, the sample frame will consist of all river stretches where it is theoretically possible to apply at least one study's field protocol. We will attribute each stretch in both frames with the following characteristics, which will be used as covariates (i.e., **domains**): (1) whether or not the stretch is significantly influenced by the presence of a major upstream spring or confluence, (2) the 'valley segment type' of the stretch (i.e., based on geographic information system [GIS] data; to allow for regional comparisons), and (3) whether or not the stretch is ephemeral (i.e., subject to intermittent flow). Other attributes are possible and will be considered. None of these attributes will be used to define sample strata; rather, they will be used during analysis to help explain variation in the measured variables.

For the five major studies at BUFF and OZAR, it is desirable for samples to be spatially balanced or "well spread-out." In river systems, space is 1-dimensional and equates with river mile. Spatial balance is important because all responses are known to be spatially autocorrelated (i.e., units close to one another tend to yield correlated responses), and park-wide inferences are desired. When responses are correlated in space, spatial balance can greatly improve precision of the resulting estimates.

Thus, we will employ the Generalized Random Tessellation Stratified (GRTS) design of sample selection. The GRTS technique generates a random sample that is spatially well balanced (see Appendix 9). It allows multiple studies to maximize overlap of selected streams by utilizing a common sample, and allows units to be added easily after an initial sample has been drawn. Additionally, because GRTS samples are not evenly spaced, it is not possible for sample locations to be in phase with a cyclic response.

The most desirable characteristic of GRTS sampling is that for any sample size, the first n stretches in the ordered GRTS sample constitute a spatially balanced sample of size n. Even if a small number of the first n units are not included in the sample, spatial balance of the GRTS sample will remain high. This characteristic is desirable because it allows multiple studies to maximize overlap and add stretches in a way that guarantees spatial balance. For example, assume 10 stretches are to be surveyed by the hellbender study, 2 stretches are to be surveyed by the geomorphology study, and 25 stretches are to be surveyed by the fish study. Under the GRTS design, and assuming all three field protocols could be applied to all stretches, the hellbender project would visit the first 10 stretches in the ordered sample. The geomorphology study would visit the first 2 stretches, and the fish project would visit the first 25 stretches in the list. In this way, overlap is maximized because 10 of 25 fish stretches would also be sampled for hellbenders, and 2 of those 10 would also receive geomorphologic measurements. Furthermore, the 2 geomorphology, 10 hellbender, and 25 fish stretches would be spatially balanced.

Panel Membership and Revisit Design

The proposed membership design is specified in Table 4-4. To select sample units for most panels, an **interpenetrating** membership design will be used, in which the sites within each panel are spatially intermixed. The only exceptions are the hellbender and heavy metal studies, in which a **dual frame** approach will be employed. Hellbenders are thought to be extremely rare and restricted to the main stem at OZAR. Panel 1 of the hellbender study will consist of only those stretches where hellbenders are known to exist. The remaining areas of the main stem rivers will be selected for the hellbender project using interpenetrating GRTS samples. For the heavy metal study, it is critical to sample the stretch containing Blair Creek, because heavy metal levels in this tributary are thought to be heavily influenced by an adjacent lead mine outside park boundaries. The Blair Creek stretch, therefore, will be placed in the heavy metal study's panel 1. All other stretches, including tributaries, will be sampled using an interpenetrating GRTS sample.

Table 4-4. Membership designs for monitoring studies proposed at BUFF and OZAR. Each study's annual sample size is assumed to be *n*

Study	Total Sample Size	Area of Inference	Panel #	# Stretches	Membership Design
Hellbender (OZAR only)	3*n*-2*k*	Known main stem hellbender stretches	1	*k*	Main stem stretches in which > 0 hellbender were found during reconnaissance surveys. Number unknown, assumed = *k*
		Unknown main stem hellbender stretches	2	*n*-*k*	First *n*-*k* main stem stretches in GRTS sample that are not known hellbender stretches.
			3	*n*-*k*	Second *n*-*k* main stem stretches in GRTS sample that are not known hellbender stretches.
			4	*n*-*k*	Third *n*-*k* main stem stretches in GRTS sample that are not known hellbender stretches.
Fish	4*n*	Stretches fishable by similar gear	1	0.25*n*	First 0.25*n* stretches in park-wide GRTS sample. Some fished with boat shocker, some with backpack shocker.
		Stretches fishable by similar gear	2	0.75*n*	First 0.75*n* stretches after panel 1 in park-wide GRTS sample. Some fished with boat shocker, some with backpack shocker.
			3	0.75*n*	Second 0.75*n* stretches after panel 1 in park-wide GRTS sample. Some fished with boat shocker, some with backpack shocker.
			4	0.75*n*	Third 0.75*n* stretches after panel 1 in park-wide GRTS sample. Some fished with boat shocker, some with backpack shocker.
			5	0.75*n*	Fourth 0.75*n* stretches after panel 1 in park-wide GRTS sample. Some fished with boat shocker, some with backpack shocker.
			6	0.75*n*	Fifth 0.75*n* stretches after panel 1 in park-wide GRTS sample. Some fished with boat shocker, some with backpack shocker.

Table 4-4. (Continued)

Geomorphology	5*n*	All stretches	1	*n*	First *n* stretches in park-wide GRTS sample.
			2	*n*	Second *n* stretches in park-wide GRTS sample.
			3	*n*	Third *n* stretches in park-wide GRTS sample.
			4	*n*	Fourth *n* stretches in park-wide GRTS sample.
			5	*n*	Fifth *n* stretches in park-wide GRTS sample.
Macroinvertebrates	3*n*	All stretches	1	0.5*n*	First 0.25*n* stretches in park-wide GRTS sample.
		All stretches	2	0.5*n*	First 0.75*n* stretches after panel 1 in park-wide GRTS sample.
			3	0.5*n*	Second 0.75*n* stretches after panel 1 in park-wide GRTS sample.
			4	0.5*n*	Third 0.75*n* stretches after panel 1 in park-wide GRTS sample.
			5	0.5*n*	Fourth 0.75*n* stretches after panel 1 in park-wide GRTS sample.
			6	0.5*n*	Fifth 0.75*n* stretches after panel 1 in park-wide GRTS sample.
Heavy metals	*n*	The Blair stretch	1	1	The Blair Creek stretch. This stretch is 1.4 km long and is potentially influenced by an adjacent mine.
		All stretches minus Blair	2	*n*-1	First *n*-1 stretches in park-wide GRTS sample that are not Blair.

The revisit design is presented in Table 4-5. With the exception of geomorphology and heavy metals, all vital signs have an always revisit panel and a set of rotating panels. Because the geomorphology and heavy metal contamination of these rivers would not be expected to change rapidly (in the absence of major flood events or new mining activity), revisiting sites on an annual basis is not likely to be informative for these vital signs. For the others, the revisit plan is a compromise between power to detect trend and precision of mean level estimates. The compromise involves allocating some fraction of annual field effort toward re-sampling stretches on a frequent basis. The remainder of annual field effort will be allocated toward re-sampling stretches on a less frequent basis. For example, in the invertebrate study, 50% of annual sample size will be dedicated to re-visiting stretches in a single panel every year. The remaining 50% of annual sample size will be dedicated to visiting one of five additional panels on a 5-year rotating basis.

Table 4-5. Revisit plans for monitoring studies proposed at BUFF and OZAR. An 'x' in the right-most columns indicates all sample units in that panel are to be visited that year

Study	Revisit Notation	Panel #	% of Annual Effort	Year 1	2	3	4	5	6	7	8	9	10	11	12
Hellbender	[1-0,1-2]	1	Unknown	x	x	x	x	x	x	x	x	x	x	x	x
		2	Unknown	x			x			x			x		
		3			x			x			x			x	
		4				x			x			x			x
Fish	[1-0,1-4]	1	25%	x	x	x	x	x	x	x	x	x	x	x	x
		2	75%	x					x					x	
		3			x					x					x
		4				x					x				
		5					x					x			
		6						x					x		
Geo-morphology	[1-4]	1	100%	x					x					x	
		2			x					x					x
		3				x					x				
		4					x					x			
		5						x					x		
Macroinvertebrates	[1-0,1-4]	1	50%	x	x	x	x	x	x	x	x	x	x	x	x
		2	50%	x					x					x	
		3			x					x					x
		4				x					x				
		5					x					x			
		6						x					x		
Heavy Metals	[1-9,1-9]	1	1 stretch	x										x	
		2	100% - 1 stretch	x										x	

We plan to coordinate the membership and revisit designs of the different monitoring protocols as much as possible. In general, co-location and co-visitation are desirable because logistics may be simplified, allowing multiple vital signs to be measured at the same location and same time by the same field crew, decreasing travel costs and time spent in the field. There is a [1-4] revisit component in 3 of the 5 proposed studies (Table 4-5).

One of two basic types of membership plans may be employed, depending upon the relative advantages of co-visiting sites. In both types of membership plans, different studies will use the same sites, resulting in a high degree of co-location. The advantage of co-locating sites, other than sampling efficiency, is that it allows the acquisition of information for multiple variables at each site. The specific membership plan will depend upon how important it is to sample the same sites for different vital signs at the same time (i.e., co-visitation).

In the first type of plan (Figure 4-3), assuming that n_1 sample units are required in panel 1, n_2 sample units are required in panel 2, and so on, the first n_1 sample units in the GRTS sample would be assigned to panel 1, the next n_2 units would be assigned to panel 2, etc. This assignment causes the sample units in each panel to interpenetrate in space due to the spatial balance inherent in the GRTS. The primary advantage of this membership design is that each panel is itself a spatially balanced sample of river stretches drawn from the entire population, and inferences can therefore be made to the entire population using data from every panel. A disadvantage of this membership design is that travel costs between sample units are higher than in some alternate plans. Thus this membership plan assures a large degree of co-location across studies, but not necessarily co-visitation.

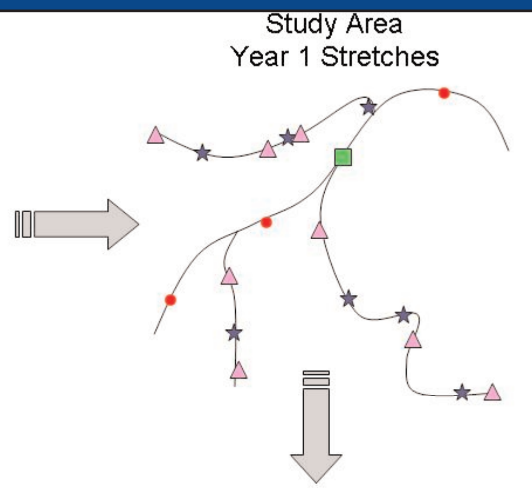
A second type of membership plan could be employed for two or more studies where co-visitation of sample units is logistically efficient (Figure 4-4). This membership design assures a large degree of co-visitation and co-location, but does not guarantee spatial balance of the total sample from studies with less than the maximum sample size. In this membership design, the study with the maximum sample size requirement would be allocated sample units as described above. Panels of other studies with the same revisit schedule, but lower sample size requirements, would be allocated a subset of the sample units.

If, for example, because of specialized expertise or seasonality issues, different sampling crews will need to visit sites independently or at different times of the year, there may be no practical benefit of co-visitation. Thus the first type of membership design described above (Figure 4-3) will be used, since it results in the highest degree of spatial balance. Alternatively, if the same sampling crews are able to obtain data for multiple vital signs from the same site at the same time, the logistical benefit may outweigh the potential sacrifice in spatial balance, and the second type of membership design (Figure 4-4) may be more appropriate.

It will be possible to utilize both membership designs, allocating some projects to one and the remainder of the other. This could, in theory, maximize spatial balance and optimize sampling logistics when considered across all projects within the limits of resources available for field work.

Figure 4-3. Potential membership plan for BUFF and OZAR yielding high co-location of points across studies, but not necessarily high co-visitation. In the table at left, a GRTS sample is allocated to panels of the macroinvertebrate, geomorphology ("geomorph"), and hellbender studies. Co-located stretches are indicated on the right. Even though stretches are co-located, some are in different panels and receive different visitation schedules. Revisit plans for panels in this example appear in Table 4-5.

GRTS Sample			Membership Plan		
Sample #	Unit ID	Location	Macro-invertebrate Study	Geo-morph Study	Hell-bender Study
1	1700	Trib	Panel 1	Panel 1	
2	2003	Main	Panel 1	Panel 1	Panel 2
3	5729	Trib	Panel 1	Panel 1	
4	5533	Trib	Panel 1	Panel 1	
5	8641	Main	Panel 1	Panel 1	Panel 2
6	489	Main	Panel 1	Panel 2	Panel 2
7	230	Trib	Panel 1	Panel 2	-
8	1460	Trib	Panel 1	Panel 2	-
9	4199	Trib	Panel 1	Panel 2	-
10	5783	Trib	Panel 1	Panel 2	-
11	19	Trib	Panel 1	Panel 3	-
12	5034	Trib	Panel 1	Panel 3	-
13	5536	Trib	Panel 2	Panel 3	-
14	9364	Trib	Panel 2	Panel 3	-
15	8830	Trib	Panel 2	Panel 3	-
16	1758	Trib	Panel 2	Panel 4	-
17	4225	Trib	Panel 2	Panel 4	-
18	9434	Trib	Panel 2	Panel 4	-
19	9179	Main	Panel 3	Panel 4	Panel 2
20	8975	Main	Panel 3	Panel 4	Panel 3
21	8002	Main	Panel 3	Panel 5	Panel 3
22	1832	Trib	Panel 3	Panel 5	-
23	958	Trib	Panel 3	Panel 5	-
24	4719	Trib	Panel 3	Panel 5	-
25	1657	Trib	Panel 4	Panel 5	-
26	9283	Trib	Panel 4	Panel 6	-
27	9181	Trib	Panel 4	Panel 6	-
28	8833	Trib	Panel 4	Panel 6	-
29	9555	Trib	Panel 4	Panel 6	-
30	5112	Trib	Panel 4	Panel 6	-

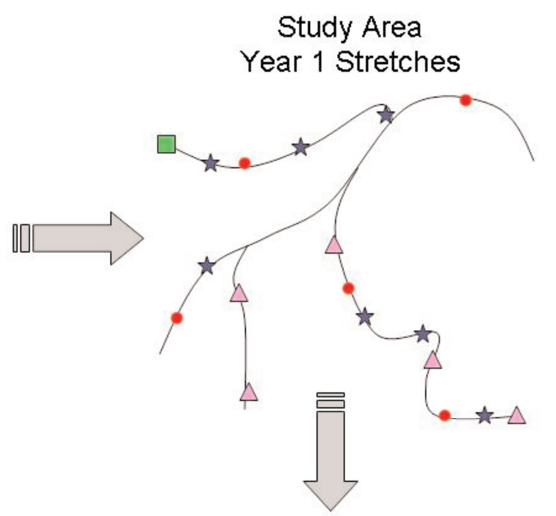


Co-Located Stretches

Symbol	Macroin.	Geomorph.	Hellbender
●	X	X	X
★	X	X	–
▲	X	–	–
■	–	–	X

Figure 4-4. Alternative potential membership plan for studies with common revisit schedules. In the table at left, stretches in the GRTS sample are first allocated to panels of the macroinvertebrate study, which has the maximum panel sizes (annual sample). Stretches are then allocated to the geomorphology ("geomorph") panels from similar numbered panels in the invertebrate study. For example, stretches in panel 1 of the geomorphology study are a subset of the stretches in panel 1 of the invertebrate study.

GRTS Sample			Membership Plan	
Sample #	Unit ID	Location	Macro-invertebrate Study	Geo-morph Study
1	1700	Trib	Panel 1	Panel 1
2	2003	Main	Panel 1	Panel 1
3	5729	Trib	Panel 1	Panel 1
4	5533	Trib	Panel 1	Panel 1
5	8641	Main	Panel 1	Panel 1
6	489	Main	Panel 1	-
7	230	Trib	Panel 1	-
8	1460	Trib	Panel 1	-
9	4199	Trib	Panel 1	-
10	5783	Trib	Panel 1	-
11	19	Trib	Panel 1	-
12	5034	Trib	Panel 1	-
13	5536	Trib	Panel 2	Panel 2
14	9364	Trib	Panel 2	Panel 2
15	8830	Trib	Panel 2	Panel 2
16	1758	Trib	Panel 2	Panel 2
17	4225	Trib	Panel 2	Panel 2
18	9434	Trib	Panel 2	-
19	9179	Main	Panel 3	Panel 3
20	8975	Main	Panel 3	Panel 3
21	8002	Main	Panel 3	Panel 3
22	1832	Trib	Panel 3	Panel 3
23	958	Trib	Panel 3	Panel 3
24	4719	Trib	Panel 3	-
25	1657	Trib	Panel 4	Panel 4
26	9283	Trib	Panel 4	Panel 4
27	9181	Trib	Panel 4	Panel 4
28	8833	Trib	Panel 4	Panel 4
29	9555	Trib	Panel 4	Panel 4
30	5112	Trib	Panel 4	-



	Co-Located		Co-Visit
Symbol	Macroin.	Geomorph.	Schedule
●	X	X	[1-0]
★	X	–	–
▲	X	X	[1-4]
■	X	–	–

CHAPTER 5: MONITORING PROTOCOLS

Introduction

Monitoring protocols identify methods for gathering information on a vital sign, outline a process to collect information, and establish how information will be analyzed and reported. Protocols are detailed study plans that are necessary to ensure that changes detected by monitoring actually are occurring in nature and do not stem from measurement variability introduced when different people or methods are used (Oakley et al. 2003). Protocols are essential for monitoring vital signs through time.

Monitoring protocols must include a narrative providing the rationale for vital sign selection, an overview of the monitoring protocol components, and a history of the development of the protocol. The narrative details protocol sampling objectives, sampling design (including location and time of sample collection), field methods, data analysis and reporting, staffing requirements, training procedures, and operational requirements (Oakley et al. 2003). Specific measurable objectives must be identified in the objective section of the narrative. Narratives also summarize the design phase of a protocol development and any decision-making that is relevant to the protocol. Documenting the history of a protocol during its development of phase helps ensure future refinement of the protocol continues to improve the protocol and is not a mere repetition of previous trials or comparisons (Oakley et al. 2003). Narratives also provide a listing and brief summary of all standard operating procedures (SOPs), which are developed in detail as independent sections in the protocol.

SOPs carefully and thoroughly explain, in a step-by-step manner, how each procedure identified in the protocol narrative will be accomplished. At a minimum, SOPs address pre-sampling training requirements, data to be collected, equipment operations, data collection techniques, data management, data analysis, reporting, and any activities required at the end of a field season (i.e., equipment storage). One SOP identifies when and how revisions to the protocol are undertaken. As stand alone documents, SOPs are easily updated compared to revising an entire monitoring protocol. A revision log for each SOP identifies any changes that are implemented.

Finally, monitoring protocols identify supporting materials critical to the development and implementation of the protocol (Oakley et al. 2003). Supporting materials are any materials developed or acquired during the development phase of a monitoring protocol. Examples of this material may include databases, reports, maps, geospatial information, species lists, species guilds, analysis tools tested, and any decisions resulting from these exploratory analyses. Material not easily formatted for inclusion in the monitoring protocol also can be included in this section.

A summary of monitoring protocols that are complete or in development is provided in the next section. The protocol summaries include the vital signs to be monitored, a justification for monitoring, a list of sampling objectives, and a description of the sample frame and revisit schedule for the parks where the protocol will be implemented. The sample frame to which a monitoring protocol will be applied may be park-wide, a habitat-type, a management unit, or any combination of the three. Notation used to depict the revisit schedule is described in Chapter 4 (pg. 4-8 to 4-10).

The sample frame and revisit schedule have not been determined in all cases, and many vital signs monitoring protocols are still under development. Protocol development summaries (PDS) are available for most monitoring protocols. Six completed protocols are also available.

Protocol Overview

Ozone Monitoring by Air Resources Division

Vital signs: Ozone

Justification: The NPS Air Resources Division (ARD) operates a network of air quality monitoring stations (sometimes referred to as the Gaseous Pollutant Monitoring Network) that measures meteorological parameters and ozone. The gaseous pollutant monitoring program determines levels of two gaseous air pollutants, ozone and sulfur dioxide, which are potentially toxic to native vegetative species found in NPS units when their levels exceed the National Ambient Air Quality Standards (NAAQS). Ozone monitoring in national parks has been ongoing since the early 1980s using EPA reference or equivalent methods. Allowing for the direct comparison of NPS data with data collected by state and local air pollution control agencies and the EPA.

Objectives:
1. Establish baseline concentrations of ozone levels in or near network parks.
2. Assess trends in ozone concentrations.
3. Determine compliance with national ambient air quality standards.
4. Provide data for the development and revision of national and regional ozone control policies that are protective of park resources.
5. Provide data for atmospheric model development and evaluation.

Park (Sampling frame [Revisit Schedule]):
All network parks (NA [continuous])

Protocol available at http://www2.nature.nps.gov/air/monitoring/docs/final_ozoneprotocol.pdf. Also, see http://www2.nature.nps.gov/air/Permits/ARIS/networks/htln.htm.

Dry Deposition Monitoring by Air Resources Division

Vital signs: Wet and Dry Deposition

Justification: The NPS monitors wet deposition through the National Atmospheric Deposition Program (NADP). NADP started in 1978 with 22 original monitoring sites and has grown to over 240 sites nationwide, providing the only long-term record of precipitation chemistry in the U.S. The Program is a cooperative effort between federal and state governments, universities and private organizations.

Objective:

1. Monitor trends in the dry deposition of sulfur and inorganic nitrogen in and near net work parks.

Park (Sampling frame [Revisit Schedule]): All network parks (NA [continuous])
Protocols available at http://www2.nrintra.nps.gov/air/monitoring/depmon.htm.
Also, see http://www2.nature.nps.gov/air/Permits/ARIS/networks/htln.htm.
See supplemental document 30.

Visibility and Particulate Matter Monitoring by Air Resources Division

Vital signs: Visibility and particulate matter

Justification: National parks and wilderness areas offer stunning mountain vistas and scenery full of unique landscapes and geologic features. The enjoyment and appreciation of these are linked to one's ability to see clearly through the atmosphere. Unfortunately, air pollution affects our ability to fully appreciate these scenic vistas. Small particles suspended in the atmosphere, mostly as a result of human-caused air pollution, often create haze -- a grey or white veil over the scene that scrubs it of its colors, forms, and textures.

The National Park Service and the U.S. Environmental Protection Agency (EPA) first began long-term visibility monitoring at selected national parks in 1979. In 1985, a national visibility monitoring program was established called Interagency Monitoring of Protected Visual Environments (IMPROVE). IMPROVE is a cooperative effort between the EPA, U.S. Forest Service, National Park Service, Fish and Wildlife Service, Bureau of Land Management, National Oceanic and Atmospheric Administration, and several interstate air quality management organizations.

Objectives:

1. Measure current visibility and aerosol conditions.
2. Document long-term visibility trends.

Park (Sampling frame [Revisit Schedule]):
All network parks (NA [continuous])

Protocol available at http://www2.nrintra.nps.gov/air/monitoring/vismon.cfm.
Also, see http://www2.nature.nps.gov/air/Permits/ARIS/networks/htln.htm.

Consolidation of Weather Service data and USGS Stream Flow Data

Vital signs: Weather, stream discharge

Justification: Weather and stream flow are critical factors limiting flora and fauna status and distribution. Therefore, this information is vitally important when interpreting monitoring information such as that collected when bird populations or aquatic invertebrate communities are sampled.

Data collected can also be used to help interpret physical and chemical properties of a stream or habitat, in addition to supporting investigations of biological communities. HTLN will use the systematic posting and retrieval of weather data collected at NWS stations, and discharge data from USGS gauging stations in support of monitoring data.

Objectives:
1. Provide daily measures of temperature, precipitation, relative humidity, wind speed, etc. in net work parks.
2. Provide daily measures of the volume of water discharged in streams in and near network parks.

Park (Sampling frame [revisit schedule]):
Nearest weather and gauging station/all network parks (NA [continuous])
Protocol and PDS not available.

Physical Habitat Monitoring of Streams and Rivers

Vital signs: Fluvial geomorphology

Justification: Watersheds in and around BUFF and OZAR have undergone significant land use changes in recent decades, leading to changes in physical habitats of their waterways. Physical processes define and maintain the aquatic habitats in which aquatic communities occur. Changes in physical habitat can cause large-scale and potentially irreversible impacts to aquatic communities. Further, physical habitat monitoring can provide the information necessary to link distant watershed disturbances to the degradation of NPS river systems. Long-term monitoring will evaluate the temporal and spatial variations in channel and flood-plain geomorphology within park boundaries and upstream contributing watersheds.

Objectives:
1. Determine the long-term temporal changes and natural variability in habitat units, channel dimensions (longitudinal profile and cross-sections), and channel hydraulic relationships.
2. Determine the sediment characteristics and natural variability of bed and bar features used to identify and qualify habitat units and monitor trends in sediment transport and bar sedimentation.
3. Determine the influence of localized habitat features, disturbance indicators, and bank erosion features on composite habitat values.
4. Determine the trends, status, and natural variability of bank erosion rates and riparian commu nities based on a geospatial analysis of channel, bar, and riparian vegetation patterns using low-altitude aerial photography.

Park (Sampling frame [Revisit Schedule]):
BUFF (Buffalo River main stem and tributaries [1-4])
OZAR (Current and Jack's Fork River main stems and tributaries [1-4])

See Supplemental Documents 28 and 29.

Stream Habitat and Riparian Assessment for Prairie Streams

Vital signs: Stream habitat/riparian assessment, stream discharge, core water quality parameters

Justification: Habitat assessment is critical for determining factors affecting water quality and the occurrence and distribution of organisms living within a stream. Data collected for stream habitat and riparian condition assessments is critical for interpreting invertebrate and fish community data, as well as physical and chemical properties of a stream.

Characterizing stream habitat and riparian conditions is an essential component of any water quality assessment program conditions, and it is necessary to weigh the cost and benefits of management and restoration activities. Habitat and riparian conditions to be measured include water depth, current velocity, point discharge, substrate size, woody debris, canopy coverage, bank vegetation cover, presence of grazing damage, bank height and slope, water clarity and chemistry (Core 5), and cross-section and channel profiles.

Objectives:

1. Determine temporal variability (among sampling years) of habitat (e.g., substrate size, woody debris) and riparian conditions (e.g., bank vegetation cover, canopy coverage) of prairie streams.
2. Determine spatial variability (among riffles and stream stretches) of habitat (e.g., substrate size, woody debris) and riparian conditions (e.g., bank vegetation cover, canopy coverage) of prairie streams.

Park (Sampling frame [Revisit Schedule]):
GWCA (Carver and William's Creek [2-5])
HOME (Cub Creek [2-5])
PIPE (Pipestone Creek [2-5])
WICR (Wilson's Creek [2-5])

See Supplemental Document 30.

Lead Monitoring at OZAR

Vital signs: Pollutant metals, Core water quality parameters

Justification: Lead and other heavy metals such as zinc, cobalt, and nickel are known to cause toxic environmental effects through accumulation in terrestrial or aquatic systems. Lead accumulation is a concern for humans and wildlife within southeast Missouri. Lead is a naturally occurring element within the Current River Basin and the southernmost extent of current lead mining operations is located only about 20 mi (32 km) northeast of OZAR. Blue Spring on the Current River has already been polluted by runoff from a mine tailings pond located in another watershed, which traveled to the spring through its underground recharge system.

Objectives:

1. Determine the current baseline levels of environmental lead and other metals (e.g., zinc, nickel, cadmium, cobalt) in the rivers of OZAR.
2. Determine the natural variability of lead concentrations occurring in the biota inhabiting these streams.
3. Determine the status and trends in environmental lead levels to better understand the dynamic nature and condition of OZAR streams and provide reference points for future comparisons.

Park (Sampling frame [Revisit Schedule]):
OZAR (Current and Jacks Fork River main stems and tributaries [1-9])

See Supplemental Document 31.

Macroinvertebrate Monitoring Protocol for Ozarks Rivers

Vital signs: Aquatic invertebrates - rivers, Core water quality parameters

Justification: BUFF and OZAR were created to preserve and interpret the free-flowing Buffalo, Jacks Fork, and Current Rivers. The Heartland Network Aquatic Resources Working Group formally agreed that the framework for aquatic monitoring at OZAR and BUFF would be directed specifically towards understanding and maintaining the ecological integrity of these river systems.

Aquatic invertebrates are an important biomonitoring tool for understanding and detecting changes in ecosystem integrity over time. Aquatic invertebrates respond rapidly to different environmental stressors, are relatively easy to collect, and can be analyzed at many different levels of precision.

Objectives:

1. Determine the annual status and trends of invertebrate species diversity, abundance and community metrics.
2. Relate the invertebrate community to overall water quality through quantification of metrics related to species richness, abundance and diversity and region specific multi-metric indices as indicators of water quality and habitat condition.

Park (Sampling frame [Revisit Schedule]):
BUFF (Buffalo River main stem and tributaries [1-0,1-4])
OZAR (Current and Jack's Fork River main stems and tributaries [1-0,1-4])

See Supplemental Document 32.

Macroinvertebrate Biomonitoring Protocol for Four Prairie Parks

Vital signs: Stream aquatic invertebrates, Core water quality parameters

Justification: The loss of North America's prairies is accompanied by a decline in the quality of streams flowing through them. These waters, which historically have served as major attractions, are now degraded to the point where contact is prohibited in three of the four parks where monitoring occurs. Land-use changes, increased nutrient loading, physical alterations to the stream and its associate riparian areas, and inputs of organic and inorganic contaminants all contribute to the degradation of these streams.

Benthic invertebrates are the most common group of organisms used to assess water quality. They are useful as indicators of anthropogenic disturbance because they represent a diverse group of relatively long-lived, largely sedentary species that react strongly and often predictably to human influences on aquatic systems. Monitoring the integrity of prairie stream ecosystems using benthic invertebrates as indicators of disturbance is necessary to support restoration efforts and management decisions affecting these resources.

Objectives:

1. Determine the annual status and trends of invertebrate species diversity, abundance, and community metrics.
2. Relate the invertebrate community to overall water quality through quantification of metrics related to species richness, abundance, diversity, and region-specific multi-metric indices as indicators of water quality and habitat condition.

Park (Sampling frame [Revisit Schedule]):
GWCA (Carver and William's Creek [1-0])
HOME (Cub Creek [1-0])
PIPE (Pipestone Creek [1-0])
WICR (Wilson's Creek and Skegg's Branch [1-0])

See Supplemental Documents 33 and 34.

Fish Community Monitoring Protocol for Ozarks Rivers

Vital signs: Fish communities - Ozarks rivers, Core water quality parameters

Justification: Two HTLN parks in the Ozark Plateaus region, BUFF and OZAR, protect major stream systems. Because fish are particularly sensitive indicators of water quality conditions, monitoring of fish communities is an essential component of water quality assessment programs within these parks. Human influences, such as changes in water chemistry or physical habitat modifications, can alter fish communities. Changes in fish community structure can be detected through changes in size components of the community, functional groups, species diversity, and relative abundance.

Objectives:

1. Determine the status and trends in the BUFF and OZAR fish communities by quantifying metrics such as species richness, percent tolerant individuals, percent invertivores, and percent omnivores, and by calculation of multi-metric indices such as indices of biotic integrity (IBI) for the main stem and tributaries in each park.

2. Estimate the spatial and temporal natural variability of fish community metric values and indices among collection sites, and examine correlations between metric values and associated habitat values (e.g., stream size characteristics, habitat availability, riparian characteristics, substrate characteristics, water quality).

Park (Sampling frame [Revisit Schedule]):
BUFF (Buffalo River main stem and tributaries [1-0,1-4])
OZAR (Current and Jack's Fork River main stems and tributaries [1-0,1-4])

See Supplemental Documents 35 and 36.

Fish Community Monitoring in Prairie Streams with Emphasis on Topeka shiner *(Notropis topeka)*

Vital signs: Fish communities - prairie streams; Topeka shiner *(Notropis topeka)*, Core water quality parameters

Justification: Trends in the composition and abundance of fish populations can be used to assess the biological integrity of prairie stream habitat. Topeka shiner (*Notropis topeka*), a federally endangered species, inhabits these small, low order prairie streams. Monitoring the current status and future population trends of this species is critical to NPS efforts toward preserving Topeka shiner populations and managing their habitats.

Objectives:

1. Determine status and trends in the distribution and abundance of Topeka shiner at Pipestone National Monument, Minnesota and Tallgrass Prairie National Preserve, Kansas.
2. Determine annual reproductive success of Topeka shiner as determined by the ratio of juveniles to adults in samples.
3. Examine correlations between Topeka shiner populations and associated habitat values (e.g., stream size characteristics, habitat availability, riparian characteristics, substrate characteristics, and water quality) to better understand their respective relationships with management actions such as grazing, prescribed fire and stream alterations.
4. Determine status and trends in species richness and relative abundance of fish communities at Pipestone National Monument, Minnesota and Tallgrass Prairie National Preserve, Kansas.

Park (Sampling frame [Revisit Schedule]):
TAPR (low order streams with sufficient water to sample [1-0, 1-4)
PIPE (Pipestone Creek [1-0])

See Supplemental Document 37 and 38.

Ozark Hellbender (*Cryptobranchus alleganiensis bishopi)* Monitoring at OZAR

Vital signs: Ozark hellbender, Core water quality parameters

Justification: The Ozark Hellbender *(Cryptobranchus alleganiensis bishopi)*, an exclusively aquatic giant salamander, was recently listed as a new federal candidate endangered species under the Endangered Species Act. Endemic to the Black and White River drainages in Arkansas and Missouri (including OZAR), this species is believed to be declining throughout its range, and no known populations appear to be stable. Park managers require population information to understand trends in abundance and distribution of *C. a. bishopi* within waters managed by the park. Ultimately a predictive assessment of the potential impacts of external and internal activities on the viability of this species must be completed.

Objectives:

1. Determine trends in the park-wide occurrence (presence/absence) and natural variability of hellbender populations in streams throughout OZAR and in population parameters such as, abundance/ density, and sex ratio, and size-class distributions.

2. Determine trends in the relationship between habitat characteristics (e.g., substrate size, water depth, current velocity, woody debris, spring inflows) and hellbender population parameters.

Park (Sampling frame [Revisit Schedule]):
OZAR (Current and Jack's Fork River main stems [1-0,1-2])

See Supplemental Document 39.

Monitoring Wetland Indicators of Ecosystem Health at CUVA

Vital signs: Wetland plant communities

Justification: Wetlands are important sites of biodiversity, and half of all endangered species are found in marshes, swamps, bogs and fens. Wetlands serve many important ecological functions, including groundwater recharge, habitat for flora and fauna, soil erosion control, chemical uptake and transformation, and flood water control. Unfortunately, over half of global wetlands have been destroyed over the past two centuries, and many of the remaining habitats have been degraded by pollution and invasion by exotic species. In the United States, 53% of all historical wetlands in the lower 48 states have been destroyed by anthropogenic causes and over 90% of Ohio's wetlands no longer exist.

In CUVA, invasive plant species and pollution are the major management issues identified. This protocol proposes to monitor wetland plant communities and the ecosystems in which they are embedded. A primary goal of this monitoring is to monitor the ecological integrity of the wetlands at CUVA, and to greatly improve our understanding of how both short-term disturbances and long-term ecosystem changes affect wetland community composition, by either promoting exotic invasion, or more hopefully, the long-term persistence of native plant communities. This protocol focuses on several short-term indicators initially, but as more years of monitoring data are accumulated, trend-based indicators will be developed based on an understanding of the normal range of variation within these systems. This monitoring data will be instrumental in supporting management decisions and restoration efforts.

Objectives:

1. Determine status, trends, and natural variability of species richness, abundance, and diversity of wetland plant communities in selected wetland types.
2. Determine status and trends in wetland habitat indicators such as nutrient regimes, water level, temperature, water chemistry, hydrological fluctuations, and isolated disturbances in hydrology.
3. Determine status and trends in the relative abundance of invasive species in wetland communities.

Park (Sampling frame [Revisit Schedule]):
CUVA (wetlands [TBD])

See Supplemental Document 40.

Invasive Plant Monitoring

Vital sign: Exotic forest / grassland plants

Justification: Invasive plants are often of concern given their abilities to reproduce prolifically, to rapidly colonize new areas, to displace native species, to alter ecosystem processes, and to detract from the interpretive value of park resources. Executive Order 13112 (1999) and two NPS documents, A Strategic Plan for Managing Invasive Non-native Plants on National Park System Lands (1996) and the 2001 Management Policies, provide clear justification for invasive plant management and monitoring in the HTLN.

Objectives:

1. To detect incipient populations (i.e., small, and localized) and new introductions of selected invasive plants before they become established in areas of management significance.
2. To determine patterns of exotic plant invasion on HTLN parks.
3. To create and maintain a list of "watch species" which are either known to exist in the region or have the potential to become problematic in the region. A similar list of no- or low-risk species should be maintained with this list. (Although these lists are not monitored per se, they are an integral part of early detection monitoring and will need to be updated frequently based on regional species alerts.)
4. To determine the trends in extent, frequency, and abundance of invasive plants on HTLN parks over 5-year intervals.

Park (Sampling frame [Revisit Schedule]):
CUVA (park-wide [1-5])
EFMO (park-wide [1-5])
GWCA (park-wide [1-5])
HEHO (park-wide [1-5])
HOCU (park-wide [1-5])
HOME (park-wide [1-5])
LIBO (park-wide [1-5])
PERI (park-wide [1-5])
PIPE (park-wide [1-5])
TAPR (park-wide [1-5])
WICR (park-wide [1-5])

See Supplemental Document 41.

Vegetation Community Monitoring

Vital signs: Prairie / forest community structure, composition, and diversity

Justification: Over the last century, large portions of grassland landscapes have been plowed for cropland or converted to pasture. Today, 71% of shortgrass prairie, 59% of mixed-grass prairie, and only 1% of original tallgrass prairie remain. The remaining grasslands have been altered through continued fragmentation and isolation, interruption of driving ecological processes such as periodic wildfire, and loss of significant faunal species.

Understanding the interactive effects of landscape scale, remnant size, community stability, and community invasibility on prairie health is integral to the preservation and protection of public lands and in determining the appropriate management strategies to employ. Resource managers require an effective plant community monitoring protocol to assess the success of their management strategies in maintaining and/or restoring prairie plant community composition, structure, and diversity. This monitoring strategy attempts to satisfy the immediate needs of managers for current information, and provide insight into the long-term changes in vegetation communities.

Objectives:

1. Determine long-term changes in vegetative structure, composition, and diversity of remnant, disturbed, and restored prairies and oak savanna/woodlands.
2. Document the annual status of plant species composition, structure, and diversity of remnant, disturbed, and restored prairies and oak savanna/woodlands at given points in time.
3. Estimate the rate at which plant species richness and Shannon diversity are changing over time, specifically as related to management efforts in restoration of prairie, savanna, woodland, and glade habitats.
4. Determine the relationship between changes in the vegetation community, environmental variables, and specific management practices in remnant, disturbed, and restored prairies and oak savanna/woodlands.

Park (Sampling frame [Revisit Schedule]):
ARPO (park-wide [2-3])
EFMO (grasslands [2-3])
EFMO (woodlands [1-2])
GWCA (park-wide [2-3])
HEHO (park-wide [2-3])
HOCU (park-wide [2-3])
HOME (park-wide [2-3])
HOSP (park-wide [2-3])
LIBO (park-wide [2-3])
PERI (park-wide [2-3])
PIPE (park-wide [2-3])
TAPR (park-wide [1-0,1-3])
WICR (park-wide [2-3])

See Supplemental Documents 42 and 43.

Western Prairie Fringed Orchid Monitoring at PIPE

Vital signs: Western prairie fringed orchid

Justification: The western prairie fringed orchid *(Platanthera praeclara)* was listed by the U.S. Fish and Wildlife Service as a federally threatened species in 1989. Once widespread from south-central Canada through the western central lowlands and eastern Great Plains of the United States, decline of the WPFO has been attributed to habitat loss to agriculture as well as hydrological change due to wetland filling (U.S. Fish and Wildlife Service 1996).

The WPFO at PIPE is found in an isolated population on approximately 4.05 hectares (10.01 acres). The population at PIPE is relatively small. The 2003 population of 221 flowering individuals was the largest observed since 1993. Close monitoring allows park staff to alter management if needed to protect this rare orchid population.

Objectives:

1. Determine long-term changes in the abundance and distribution of flowering WPFO individuals at PIPE.
2. Measure long-term changes in plant reproduction (number of flowers, number of fruits, fruit quality) of the WPFO population.
3. Evaluate relationships between prescribed fire implementation, precipitation, population size, reproduction, and plant height.

Park (Sampling frame [Revisit Schedule]):
PIPE (park-wide [1-0])

See Supplemental Documents 44 and 45.

Missouri Bladderpod Monitoring at WICR

Vital signs: Missouri bladderpod

Justification: Missouri bladderpod ***(Lesquerella filiformis)*** was listed as endangered in 1987. Five populations are known from WICR. This diminutive winter annual is restricted to limestone glades and rock outcrops in southwestern Missouri and northwestern Arkansas. Habitat conversion for urban development or agriculture threatens this species across its range. The habitat structure of the limestone glades has been altered by woody species encroachment, a result of suppression of the periodic wildfires that historically maintained an open canopy on these glades. Glade habitat has also been altered and threatened by exotic plant establishment-of particular concern are annual exotics such as hop clover (***Trifolium campestre and T. dubium)*** and brome grass (***Bromus*** species), which compete directly with Missouri bladderpod (Thomas and Jackson 1990).

Objectives:

1. Determine long-term changes in the abundance and flowering of the Missouri bladderpod population on Bloody Hill Glade at WICR.
2. Measure and relate plant occurrence, reproduction and persistence to glade location and glade habitat characteristics. Glade habitat characteristics include canopy, substrate, and native and exotic plant cover.

Park (Sampling frame [Revisit Schedule]):
WICR (glade habitat [1-0])

See Supplemental Documents 46 and 47.

Bird Monitoring Protocol

Vital signs: Land birds

Justification: Birds are an important component of park ecosystems, and their high body temperature, rapid metabolism, and high ecological position in most food webs make them a good indicator of the effects of local and regional changes in ecosystems. Many grassland avian species demonstrate declining abundance as their habitat loss continues. Data collected during the U.S. Geological Survey's annual North American Breeding Bird Surveys (BBS) between 1966 and 1999 indicates that 70% of 29 grassland bird species show evidence of population declines (Sauer et al. 2003). Many prairie species such as the grasshopper sparrow ***(Ammodramus savannarum)***, eastern meadowlark ***(Sturnella magna),*** horned lark ***(Eremophila alpestris),*** bobolink ***(Dolichonyx oryzivorus)***, lark bunting ***(Calamospiza melanocrys)***, and dickcissel ***(Spiza americana)*** have declined at alarming rates. The destruction and fragmentation of prairie landscapes, as well as structural degradation (e.g., fire suppression, changes in grazing regimes) of remaining prairie habitats have contributed to these declines.

Long-term trends in the community composition and abundance of breeding bird populations provide a measure for assessing the ecological integrity of prairie systems. Monitoring long-term patterns in grassland bird communities in relation to vegetation structure resulting from fire and grazing will improve understanding of management actions.

Objectives:

1. Determine annual changes in the species composition and abundance of bird species that occur in the parks during the breeding season.
2. Improve our understanding of breeding bird - habitat relationships and the effects of management actions such as grazing and prescribed fire regimes on bird populations by correlating changes in bird species composition and abundance with changes in specific habitat variables (e.g. vegetation structure, ground cover).

Park (Sampling frame [Revisit Schedule]):
HEHO (park-wide [TBD])
HOCU (park-wide [TBD])
TAPR (park-wide [1-0, 1-5])

See Supplemental Documents 48 and 49.

White-Tailed Deer Monitoring Protocol

Vital signs: White-tailed deer

Justification: Lack of natural predators in most Midwestern parks render deer populations vulnerable to diseases arising from overpopulation. As long as food is available and mortality low, deer populations increase rapidly. An overabundance of deer may contribute to over-browsing of vegetation, which can reduce plant diversity, change the functioning of a plant community, and increase the potential for invasion by exotic species.

Deer are also involved in collisions with motor vehicles within the parks and in surrounding areas. Information regarding deer populations enables land managers to conduct appropriate controls to ensure that vegetation within a park is not negatively impacted and the incidence of vehicle - deer collisions minimized.

Objectives:
1. Determine annual status and long-term trends of white-tailed deer numbers within each park.

Park (Sampling frame [Revisit Schedule]):
ARPO (park-wide [1-0])
LIBO (park-wide [TBD])
PERI (park-wide [1-0])
WICR (park-wide [1-0])

See Supplemental Document 50.

Land Use, Land Cover Monitoring Protocol

Vital signs: Land cover / land use

Justification: Many of the parks in the HTLN are subject to encroaching agricultural, residential, and urban development, and recognize that these landscape issues are closely linked to park ecosystem function. Thus, land-use change is a high priority for long-term monitoring within the HTLN vital signs monitoring program. Long-term monitoring of landscape-level indicators that represent the ecological impacts of land use changes may help managers to determine patterns that may threaten future ecological integrity within parks. Hot Springs National Park (HOSP) is the subject of our pilot project for protocol development. HOSP and other parks in the network have mandates focusing on the maintenance of pristine water quality within the park. Land use changes altering the flow of water through the park are the greatest threat to water quality. Additionally, the increasing human population in the area surrounding the park has led to increases in recreational use within the park further threatening park water resources.

Objectives:
1. Determine long-term trends in land-use change adjacent to HTLN parks.
2. Determine the rate and distribution of urban expansion within the watershed of HTLN parks.
3. Determine habitat conversion to urban landscapes, creation of edge effects, reduction of functional ecosystem size, and elimination of important habitats.

Park (Sampling frame [Revisit Schedule]):
BUFF (park-wide [1-9])
EFMO (park-wide [1-9])
HOSP (park-wide [1-9])
LIBO (park-wide [1-9])
OZAR (park-wide [1-9])
PERI (park-wide [1-9])
PIPE (park-wide [1-9])
WICR (park-wide [1-9])

See Supplemental Document 51.

Table 5-1. Implementation information for vital signs monitoring.

Vital Sign	Protocol Name	Attributes Measured	Protocol Developed by:	Protocol Implemented by:	NPS Contact
Ozone	NPS Air Atlas	Ground level ozone concentrations	NPS Air Resources Division	NPS Air Resources Division	Program Coordinator
Wet and Dry Deposition	NPS Air Atlas	Wet deposited inorganic nitrogen and sulfure	NPS Air Resources Division	NPS Air Resources Division	Program Coordinator
Visibility and Particulate Matter	NPS Air Atlas	Light extinction (i.e. light lost to absorption by particles)	NPS Air Resources Division	NPS Air Resources Division	Program Coordinator
Weather	Consolidation of Weather Service data and USGS Stream Flow Data	Daily ambient temperature, precipitation, max. temp., min. temp., degree days	National Weather Service and Atmospheric Science Program, University of Missouri – Columbia	National Weather Service and Atmospheric Science Program, University of Missouri – Columbia	Wildlife Ecologist
Fluvial Geomorphology	Physical Habitat Monitoring of Streams and Rivers	Channel longitudinal profile, cross section, channel planform, bank stability, sediment composition, photomonitoring	Missouri State University	NPS - HTLN	Aquatics Program Leader
Stream Habitat/Riparian Assessment	Stream Habitat and Riparian Assessment for Prairie Streams	Bank erosion (stability), banks substrate type, bank height and slope, bank vegetation condition, riparian vegetation condition, substrate characteristics, embeddedness, woody debris, vegetation cover	NPS – Prairie Cluster Prototype	NPS - HTLN	Aquatics Program Leader
Stream Discharge	1) Consolidation of Weather Service data and USGS Stream Flow Data 2) Stream Habitat and Riparian Assessment for Prairie Streams	Volume of water discharged	1) USGS and Atmospheric Science Program, University of Missouri – Columbia 2) NPS – Prairie Cluster Prototype	1) US Geological Survey and Atmospheric Science Program, University of Missouri – Columbia 2) NPS - HTLN	1) Wildlife Ecologist 2) Wildlife Ecologist
Core Water Quality Parameters	1) Stream habitat and Riparian Assessment for Prairie Streams 2) Fish Community Monitoring in Prairie Streams with Emphasis on Topeka Shiner (*Notropis topeka*) 3) Macroinvertebrate Biomonitoring Protocol for Four Prairie Parks 4) Macroinvertebrate Monitoring Protocol for Ozarks rivers	For all protocols: temperature, conductivity, pH, dissolved oxygen, turbidity	1) NPS - Prairie Cluster Prototype 2) NPS - Prairie Cluster Prototype 3) MO Field Station, NPWRC, Biological Resources Division, U.S. Geological Survey 4) NPS – HTLN	1) NPS – HTLN 2) NPS – HTLN 3) NPS – HTLN and park Resource Managers 4) NPS - HTLN	1) Aquatics Program Leader 2) Fisheries Biologist 3) Aquatics Program Leader 4) Aquatics Program Leader
Pollutant Metals	Lead (Pb) Monitoring Protocol for HTLN	Lead levels in crayfish and clam tissue	Columbia Environmental Research Center, US Geological Survey	TBD	Aquatics Program Leader
Aquatic Invertebrates—Prairie Streams	Macroinvertebrate Biomonitoring Protocol for Four Prairie Parks	Species richness and abundance, indices of biological integrity including: family biotic index, and EPT ratio	MO Field Station, NPWRC, Biological Resources Division, U.S. Geological Survey	NPS – HTLN and park Resource Managers	Aquatics Program Leader
Aquatic Invertebrates—Rivers	Macroinvertebrate Monitoring Protocol for Ozarks Rivers	Species richness and abundance, indices of biological integrity including: family biotic index, and EPT ratio	NPS – HTLN	NPS - HTLN	Aquatics Program Leader
Exotic Forest Plants	Invasive Non-native Plant Monitoring in HTLN Parks	Presence, abundance, distribution, rate of spread	NPS - HTLN	NPS - HTLN	Botanist
Exotic Grassland Plants	Invasive Non-native Plant Monitoring in HTLN Parks	Presence, abundance, distribution, rate of spread	NPS - HTLN	NPS - HTLN	Botanist
Wetland Plant Communities	Monitoring Wetland Indicators of Ecosystem Health	Water level, water chemistry, wetland vegetation, soils, litter decomposition, habitat variables	NPS – CUVA and University of Akron	TBD	Aquatics Program Leader
Prairie Community Structure, Composition, and Diversity	Vegetation Community Monitoring Protocol for HTLN	Species richness, diversity and abundance, frequency, vegetation structure, habitat characteristics, photomonitoring	NPS – Prairie Cluster Prototype, Nature's Keepers Services and MO Field Station, NPWRC, Biological Resources Division, U.S. Geological Survey	NPS - HTLN	Plant Ecologist
Forest Community Structure, Composition, and Diversity	Vegetation Community Monitoring Protocol for HTLN	Species richness, diversity and abundance, frequency, vegetation structure, habitat characteristics, photomonitoring	NPS – HTLN, Nature's Keepers Services and MO Field Station, NPWRC, Biological Resources Division, U.S. Geological Survey	NPS - HTLN	Plant Ecologist
Fish Community—Prairie Streams	Fish Community Monitoring in Prairie Streams with Emphasis on Topeka Shiner (*Notropis topeka*)	Species richness, diversity and abundance, species-habitat relationships	NPS - Prairie Cluster Prototype	NPS - HTLN	Fishery Biologist
Fish Community—Ozark Rivers	Fish Community Monitoring Protocol for Ozarks Rivers	Species richness, diversity and abundance, indices of community structure and biotic integrity including: percent of individuals of tolerant species.	Arkansas District, Water Resources Division, U.S. Geological Survey	NPS - HTLN	Fishery Biologist
Landbirds	Bird Monitoring Protocol for HTLN	Species richness, diversity and abundance, proportion of sites occupied, habitat characteristics, species-habitat relationships	NPS - Prairie Cluster Prototype	NPS - HTLN	Wildlife Ecologist
Deer	White-Tailed Deer Monitoring Protocol for HTLN	Abundance, density, and distribution	NPS - HTLN	NPS - HTLN	Wildlife Ecologist
Missouri Bladderpod	Missouri Bladderpod Monitoring Protocol for WICR	Population size, density, reproduction, habitat characteristics, and plant-habitat relationships	Truman State University and MO Field Station, NPWRC, Biological Resources Division, U.S. Geological Survey	NPS - HTLN	Botanist
Ozark Hellbender	Ozark Hellbender (*Cryptobranchus alleganiensis bishopi*) Monitoring Protocol for OZAR	Population size and distribution	Center for Biodiversity, Illinois Natural History Survey	TBD	Aquatics Program Leader
Topeka Shiner	Fish Community Monitoring in Prairie Streams with Emphasis on Topeka Shiner (*Notropis topeka*)	Population size and distribution, reproductive success, species-habitat relationships	NPS - Prairie Cluster Prototype	NPS - HTLN	Fishery Biologist
Western Prairie Fringed Orchid	Western Prairie Fringed Orchid Monitoring Protocol for PIPE	Population size, distribution, reproduction, and plant-habitat relationships	MO Field Station, NPWRC, Biological Resources Division, U.S. Geological Survey	NPS - HTLN	Botanist
Land Cover/Land Use	Land Use, Land Cover Monitoring Protocol for HTLN	Area and distribution, fragmentation and connectivity, invasion corridors, patch characteristics, land use conversion rate, land use change analysis, census data	University of Arkansas at Monticello	TBD	GIS Specialist

CHAPTER 6: DATA MANAGEMENT

Information is the common currency among the activities and staff involved in natural resource management in the National Park Service (NPS). The central mission of the National Park Service's Inventory and Monitoring (I&M) Program is to acquire, manage, analyze, and distribute scientific information on the status and trends of specific park natural resources. Intended users of this information include park managers, cooperators, researchers, and the general public.

A cornerstone of the Inventory and Monitoring Program is the strong emphasis placed on data management. The Heartland Network (HTLN) expects to invest at least thirty percent of its available resources in data management, analysis, and reporting activities.

Because of the size and complexity of the elements comprising network data management, a separate Data Management Plan has been developed and is included in this report as Supplemental Document 52.

The HTLN Data Management Plan

The goal of the Heartland Network's data management program is to maintain, in perpetuity, the ecological data and related analyses that result from the network's inventory and monitoring work. The HTLN Data Management Plan describes the resources and processes required to ensure the accuracy, security, longevity, and accessibility of data acquired or managed by the HTLN.

Data Accuracy

The quality of the data collected and managed by the I&M Program is paramount. Analyses performed to detect ecological trends or patterns require data with minimal error and bias. Inconsistent or poor-quality data can limit the detection of subtle changes in ecosystem patterns and processes, lead to incorrect interpretations and conclusions, and could greatly compromise the credibility and success of the I&M Program. To ensure that the HTLN produces and maintains data of the highest possible quality, procedures are established to identify and minimize errors at each stage of the data lifecycle.

Data Security

Digital and hard-copy data must be maintained in environments that protect against loss, either due to electronic failure or to poor storage conditions. Digital data of the HTLN are stored in multiple formats on a secure server, and are part of an integrated backup routine that includes rotation to off-site storage locations.

In addition, the HTLN is working with NPS museum curators and archivists to ensure that related project materials such as field notes, data forms, specimens, photographs, and reports are properly cataloged, stored, and managed in archival conditions.

Data Longevity

Countless data sets have become unusable over time either because the format is outdated (e.g., punchcards), or because metadata is insufficient to determine the data's collection methods, scope and intent, quality assurance procedures, or format. Basic components of data longevity include proper storage conditions, backups, and migration of data sets to current platforms and software standards are basic components of data longevity. Comprehensive data documentation is another essential component. The HTLN uses a suite of metadata tools to ensure that data sets are consistently documented, and in formats that conform to current federal standards.

Data Accessibility

One of the most important responsibilities of the Inventory and Monitoring Program is to ensure that data collected, developed, or assembled by the HTLN staff and cooperators are made available for decision-making, research, and education. Providing well-documented data in a timely manner to park managers is especially important to the success of the program. The HTLN must ensure that:

- Data are easily located and obtained
- Data are subjected to full quality control before release
- Data are accompanied by complete metadata
- Sensitive data are identified and protected from unauthorized access and distribution

The HTLN's main mechanism for distribution of the network's inventory and monitoring data will be the Internet, which will allow data and information to reach a broad community of users. As part of the NPS I&M Program, web-based applications and repositories have been developed to store a variety of park natural resource information (Table 6-1).

Table 6-1. Data provided on the HTLN and national I&M websites

Web Application Name	Data available at site
NPSpecies	Database of vascular plant and vertebrate species known or suspected to occur on NPS park units (NPSpecies Home Page).
NatureBib	Bibliography of park-related natural resource information (NatureBib Home Page)
NPSFocus	Portal to a variety of NPS information sources; will include NatureBib and NR/GIS Data Store links
Biodiversity Data Store	Digital archive of documents, GIS datasets and non-GIS dataset files that document the presence/absence, distribution and/or abundance of taxa in National Park Service units (Biodiversity Service Center Home Page)
NR-GIS Data Store	Park-related metadata and selected data sets (spatial and non-spatial) — *under development*
HTLN Website	Reports and metadata for the HTLN projects; certified species lists; search and reporting tools for data; data downloads; database templates (HTLN Home Page)

The Heartland Network's information acquires its real value when it reaches those who can apply it.

If these web portals do not meet a specific user's requirements, HTLN data management staff will work with users on an individual basis to ensure receipt of the desired information in the requested format.

Data Sources and Priorities

There are multiple sources of significant data related to natural resources in the HTLN parks. The types of work that may generate these data include:

- Inventories
- Monitoring
- Protocol development pilot studies
- Special-focus studies performed by internal staff, contractors, or cooperators
- External research projects
- Studies performed by other agencies on park or adjacent lands
- Resource impact evaluations related to park planning and compliance
- Resource management and restoration work

Prioritizing data management efforts in a sea of unmanaged data

- Highest priority is to produce and curate high-quality, well-documented data originat ing with the Inventory and Monitoring Program.
- Assist with data management for current projects, legacy data, and data originating out side the Inventory and Monitoring Program that complement program objectives.
- Help ensure good data management practices for park-based natural resource projects that are just beginning to be developed and implemented.

HTLN's first data management priority is natural resource inventories and long-term monitoring. However, the standards, procedures, and approaches to data management developed by the HTLN are being applied to other natural resource data sources.

For example, all natural resource parks need a basic suite of resource inventory data in order to manage effectively their resources and support a successful monitoring program. The national Inventory and Monitoring Program has determined that a minimum of 12 inventory data sets, including both biotic and abiotic components, should be acquired by all parks. The HTLN is working with individual parks and national NPS programs to acquire and standardize these basic resource data sets, and make them widely available.

The data sets are:

- Natural resource bibliography
- Base cartographic data
- Geology map
- Soils map
- Weather data
- Air quality data
- Location of air quality monitoring stations
- Water body location and classification
- Water quality data
- Vegetation map
- Species distribution and status of vertebrates and vascular plants
- Documented species list of vertebrates and vascular plants

Data Management Categories

Data from park and network sources can generally be placed in the following data management categories:

1. Data managed in service-wide databases.

The HTLN uses three databases developed by the I&M WASO office. NatureBib is a bibliographic tool for cataloging reports, publications, or other documents that relate to natural resources in park units. Dataset Catalog is used to document primarily non-spatial natural resource-related databases or other data assemblages. NPSpecies is used by the network to develop and maintain lists of vertebrates and vascular plants in network parks, along with associated supporting evidence.

2. Data developed or acquired directly by the network as a result of inventory, monitoring, or other projects, and managed by the HTLN.

This category includes project-related protocols, field data, reports, spatial data, and associated materials such as field forms and photographs provided to the HTLN by contractors or developed by the HTLN staff. Projects can be short-term (one to three years duration) or long-term (ongoing monitoring).

3. Data that, while not developed or maintained by the HTLN, are used as primary data sources or provide context to other data sets.

Examples of this category include: GIS data developed by parks, other agencies or organizations; national or international taxonomic or other classification systems; climate, air quality, or hydrologic data collected or assembled by regional or national entities.

4. Data acquired and maintained by network parks that the HTLN assists in managing.

Because of the lack of data management expertise in many network parks, the HTLN provides data management assistance for high-priority data sets or those that may benefit from standardized procedures. Examples include: a multi-park database for rare plant data; data sets of legacy natural resource monitoring data; and data on exotic invasive plant species.

These above categories can contain one or more of the following data formats:

- Hard-copy documents (e.g., reports, field notes, survey forms, maps, refer ences, administrative documents)
- Physical objects (e.g., specimens, sam ples, photographs, slides)
- Electronic text files (e.g., Word files, email, websites)
- Electronic tabular data (e.g., databases, spreadsheets, tables, delimited files)
- Spatial data (e.g., shapefiles, coverages, remote-sensing data)
- Miscellaneous electronic files (images, sounds, other files with proprietary formats)

Each of these data formats has specific requirements for ongoing management and maintenance, which are addressed in the Data Management Plan.

Data Management and the Project Lifecycle

Inventory and monitoring projects are typically divided into five broad stages: planning and approval; design and testing; implementation; product integration; and evaluation and closure (Fig. 6-1).

During all stages data management staff collaborate closely with project leaders and participants.

Specific data management procedures correspond to these stages and are fully detailed in the chapters of the Data Management Plan.

Building upon the data management framework presented in the Plan, chapters are devoted to:

- data acquisition and processing
- a framework verifying and validating data
- dataset documentation
- reporting
- data dissemination
- long-term maintenance, storage, and security of HTLN data.

For monitoring projects, extensive protocol Standard Operating Procedures (SOPs) provide detailed guidance on all stages of a project's data lifecycle. These SOPs are specific to each project, yet all fall within the guidelines established in the Data Management Plan.

Water Quality Data

Water quality data collected as part of the network's monitoring program have distinct data management requirements. Data must be managed according to guidelines from the NPS Water Resources Division (WRD), including using the NPSTORET desktop database application at the parks to help manage data entry, documentation, and transfer to WRD. The HTLN will oversee the use of NPSTORET according to the network's water quality monitoring protocol, and will ensure the content is transferred at least annually to NPS Water Resource Division for upload to the Environmental Protection Agency's STORET (STORage and RETrieval) database (Fig. 6-2).

Figure 6-1. Model of data lifecycle stages and associated activities for the Heartland Network

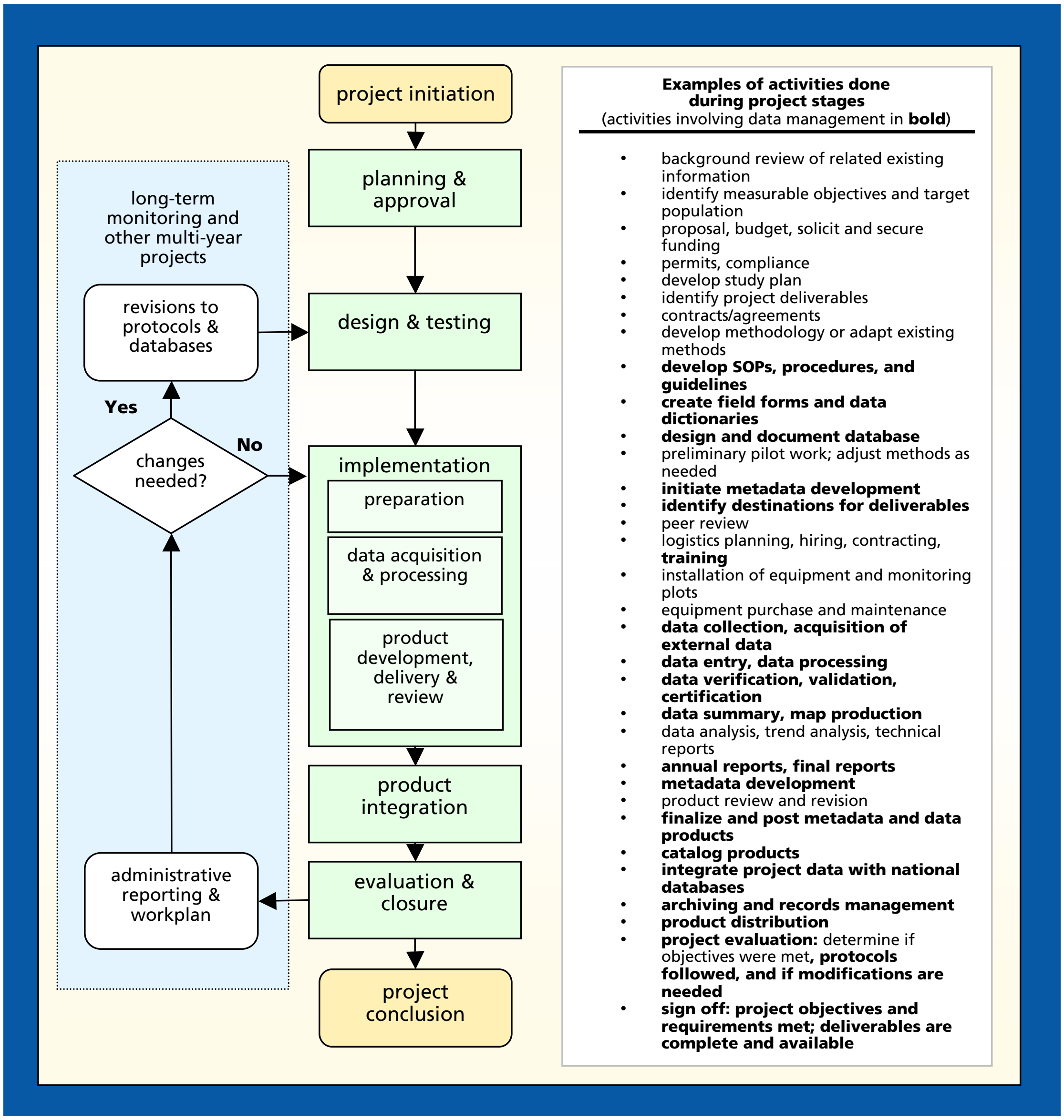
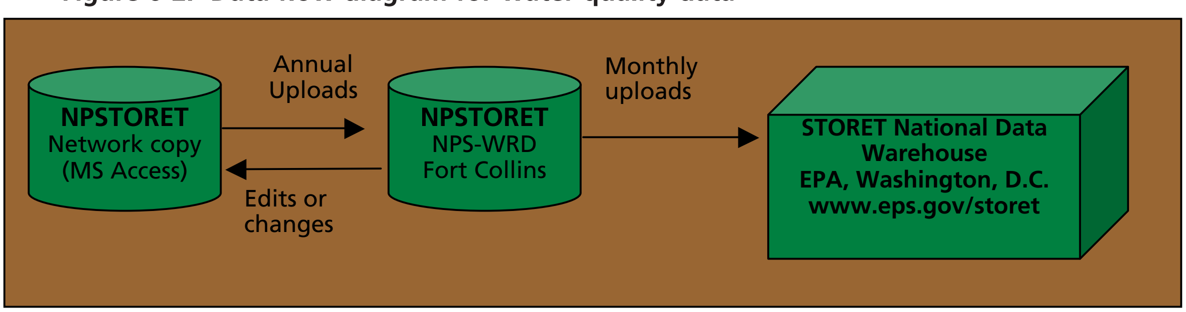


Figure 6-2. Data flow diagram for water quality data



Data Management Plan Maintenance

The HTLN approach is to maintain a Data Management Plan that is useful to a broad audience, and that can provide guidance on data management practices at a number of different levels. The HTLN hopes to keep the plan simple, flexible, and evolving, and to include data users in the decision-making process whenever possible.

The document will undergo an initial prescribed review process that will include both an internal network review (i.e., by members of the technical committee and network staff), and a service-wide review that involves the regional data/GIS coordinator and data management staff from the NPS Washington Office I&M Program. External reviewers from other agencies will also be sought to provide a more balanced and comprehensive review of this plan.

The HTLN will update the plan to ensure that it reflects accurately the network's current standards and practices. Recommendations for changes can be forwarded to the network data manager by any interested party or user of network inventory and monitoring data (e.g., park resource managers, project leaders, technicians, superintendents, external users). These recommendations will be discussed by data management and network staff and actions decided upon. Simple changes can be made immediately in the document, while substantive changes will be made during version updates. Plan updates will be distributed to members of the network Technical Committee before implementation. Otherwise, the plan will be scheduled for a full revision and review at a minimum of every five years.

The most current version of the plan is available on the HTLN website.

CHAPTER 7: DATA ANALYSIS AND REPORTING

Overview

In this chapter, we describe how the data collected by the HTLN will be analyzed, and how the information resulting from such analyses will be assimilated and distributed in the form of reports. A summary of all monitoring projects, the kinds of information they generate, and the responsible personnel is presented in Table 7-1. Communication is critical in the final delivery of HTLN information products. HTLN reports are written to meet a wide array needs for information users, including the HTLN Board of Directors, HTLN Technical Committee, service-wide managers, park resource managers, park interpreters, the general public, external scientists, and others. A brief description of each report type, its primary audience, and the peer-review process it undergoes is given in Table 7-2.

Analysis

In a diverse, long-term monitoring program such as this one, the primary focus will be on trend (i.e., change over time). For each vital sign, we will estimate parameter(s) of interest (e.g., mean population size, diversity indices, etc.) for each park and year sampled. Each parameter will be accompanied by a measure of the associated reliability or uncertainty (e.g., standard deviation, 95% confidence interval). A simple graphical representation of the estimated parameters (along with their associated variabilities) over time will provide a very simple, yet powerful means of conveying information on trends. For any time period(s) of interest, one may ascertain whether the parameter is increasing, decreasing, or not changing significantly. Such information will be readily accessible and easily interpreted by a diverse audience, including resource managers, park superintendents, and other scientists.

When it is desirable to test specific statistical hypotheses, we will employ the appropriate statistical test(s). Tests frequently used to elucidate trends include regression analyses, repeated measures analysis of variance, and times series analyses (see Appendix 10 and 11). In a long-term program such as this, a great diversity of potential statistical hypotheses could be posed, and a large number of potential statistical analyses could be employed. There exist many approaches to trend analysis, and the appropriate statistical test will depend on the particular question and data structure. Potential analytic approaches to HTLN vital signs are indicated in Table 7-1. Details on the statistical analyses for each vital sign may be found in the individual protocol development summaries.

An important issue in testing for trends is whether an analysis will be able to detect a biologically important change if one in fact exists. The greater the statistical power of the analysis, the more likely one will detect such a change. In designing our protocols, we will use prospective power analyses to determine whether sample sizes, measurement techniques, etc. will yield sufficient statistical power.

Retrospective power analysis is usually not useful (and largely unnecessary if the appropriate prospective power analysis has been calculated). Confidence intervals surrounding parameter estimates convey similar information.

Feedback from resource managers based on early results will almost certainly generate questions and hypotheses not currently of obvious interest. Thus, to accommodate future issues and concerns, we strive to provide timely information to resource managers and remain flexible in our approaches to statistical analyses.

Table 7-1. Summary of HTLN Vital Signs Monitoring projects

Vital Sign	Project leader	Information content	Potential types of analyses
Ozone	Program Coordinator	Hourly ground-level ozone concentrations, ozone dose parameters indices to quantify ozone exposure to plants	Descriptive statistics; parameter estimation with associated confidence intervals.
Wet and Dry Deposition	Program Coordinator	Kilogram per hectare per year of deposited inorganic nitrogen and sulfer	Descriptive statistics; parameter estimation with associated confidence intervals.
Visibility and Particulate Matter	Program Coordinator	Light extinction (i.e. light lost to absorption by airborne particles) on the 20% clearest and 20% haziest days	Descriptive statistics; parameter estimation with associated confidence intervals.
Weather	Wildlife Ecologist	Daily ambient temperature, precipitation, maximum temperature, minimum temperature, and degree days	Descriptive statistics; parameter estimation with associated confidence intervals.
Fluvial Geomorphology	Aquatics Program Leader	Channel longitudinal profile, cross section, channel planform, bank stability, sediment composition, and photomonitoring	Descriptive statistics; parameter estimation with associated confidence intervals.

Table 7-1 continued

Stream Habitat / Riparian Assessment	Aquatics Program Leader	Bank erosion (stability), bank substrate type, bank height and slope, bank vegetation condition, riparian vegetation condition, substrate characteristics, embeddedness, woody debris, and vegetation cover	Descriptive statistics; parameter estimation with associated confidence intervals.
Stream Discharge	Wildlife Ecologist	Cubic feet per second of water discharged from streams	Descriptive statistics;, parameter estimation with associated confidence intervals.
Core Water Quality Parameters	Aquatics Program Leader	Temperature, conductivity, pH, dissolved oxygen, turbidity	Descriptive statistics; parameter estimation with associated confidence intervals.
Pollutant Metals	Aquatics Program Leader	Lead and other metals in water, sediments, and animal tissue	Descriptive statistics; nonparametric correlation, environmental availability and uptake.
Aquatic Invertebrates—Prairie Streams	Aquatics Program Leader	Species richness and abundance; indices of biological integrity including family biotic index and EPT ratio	Descriptive statistics; similarity/diversity measures; nonparametric correlation with Core 5 and habitat variables; analyses of variance and non-parametric analogues.
Aquatic Invertebrates—Rivers	Aquatics Program Leader	Species richness and abundance; indices of biological integrity including family biotic index, EPT ratio, and community index	Descriptive statistics; similarity/diversity measures; nonparametric correlation with Core 5 and habitat variables; analyses of variance and non-parametric analogues.
Exotic Forest Plants	Botanist	Presence, abundance, distribution, and rate of spread	Number of new occurrences of exotic plants (or patch size).
Exotic Grassland Plants	Botanist	Presence, abundance, distribution, and rate of spread	Number of new occurrences of exotic plants (or patch size).
Wetland Plant Communities	Aquatics Program Leader	Water level, water chemistry, wetland vegetation, soils, litter decomposition, and habitat variables	Descriptive statistics; similarity/diversity measures; nonparametric correlation with water chemistry & habitat variables; analyses of variance and non-parametric analogues.

Table 7-1 continued

Prairie Community Structure, Composition, and Diversity	Plant Ecologist	Species richness, diversity, abundance, and frequency; vegetation structure; habitat characteristics; and photomonitoring	Descriptive statistics of species frequency, foliar cover, and community indices (e.g. richness, diversity). Geostatistical analysis of spatial patterns of abundance and diversity. Repeated measures analysis of variance.
Forest Community Structure, Composition, and Diversity	Plant Ecologist	Species richness, diversity, abundance, and frequency; vegetation structure; habitat characteristics; and photomonitoring	Descriptive statistics of species frequency, foliar cover, and community indices (e.g. richness, diversity). Geostatistical analysis of spatial patterns of abundance and diversity. Repeated measures analysis of variance.
Fish Communities—Prairie Streams	Fishery Biologist	Species richness, diversity, abundance; species-habitat relationships	Descriptive statistics; similarity/diversity measures; nonparametric correlation with Core 5 and habitat variables; analyses of variance and non-parametric analogues.
Fish Communities—Ozark Rivers	Fishery Biologist	Species richness, diversity, and abundance; indices of community structure and biotic integrity including percent of individuals of tolerant species and percent of individuals of invertebrates	Descriptive statistics; similarity/diversity measures; nonparametric correlation with Core 5 and habitat variables; analyses of variance and non-parametric analogues.
Landbirds	Wildlife Ecologist	Species richness, diversity and abundance; proportion of sites occupied; habitat characteristics; and species-habitat relationships	Descriptive statistics and distance estimation to address detection bias and percent area occupied. Geostatistical analysis of spatial patterns of diversity and abundance. Repeated measures analysis of variance.
Deer	Wildlife Ecologist	Abundance, density, and distribution	Descriptive statistics; parameter estimation with associated confidence intervals.

Table 7-1 continued

Missouri Bladderpod	Botanist	Population size, density, reproduction, habitat characteristics, and plant-habitat relationships	Estimation of population size and variance using adaptive sampling techniques. Correlation analysis between plant abundance and habitat characteristics (e.g. soil, vegetation cover). Geostatistical analysis of spatial patterns of abundance.
Ozark Hellbender	Aquatics Program Leader	Population size and distribution	Descriptive statistics; nonparametric correlation (Spearman R or Kendall Tau) of hellbender occurrence with habitat variables.
Topeka Shiner	Fishery Biologist	Population size and distribution, reproductive success, and species-habitat relationships	Descriptive statistics; individual counts and shiner distribution mapped by NHD hydrography.
Western Prairie Fringed Orchid	Botanist	Population size, distribution, reproduction, and plant-habitat relationships	Descriptive statistics, parameter estimation with associated confidence intervals.
Land Cover / Land Use	GIS Specialist	Area and distribution, fragmentation and connectivity, invasion corridors, patch characteristics, land use conversion rate, land use change analysis, census data	Geostatistical analysis of spatial patterns of land cover and land use.

Reporting

A diversity of reports will be produced (Table 7-2). Collectively, these reports will disseminate information to a wide audience, including park superintendents, resource managers, interpretive staff, other scientists, and the general public. One important goal in reporting is to produce information in a timely manner, to provide resource managers feedback to assess ongoing management practices. Annual status reports for each vital sign will be the primary vehicle for accomplishing this goal. The project leader of each vital sign will prepare the respective annual status report with the assistance of the data manager. Annual status reports will primarily include summary analyses consisting of descriptive statistics and graphical representations of data and will be designed to be easily interpretable.

A second major goal is to be able to discern biologically important trends in the data. The long-term (5 - 7 year) Comprehensive trends analysis and synthesis reports will focus on elucidating such trends. The project leader will prepare the long-term trends reports with the assistance of the quantitative ecologist.

A third goal in reporting is to ensure the information reaches the widest audience possible. Thus, we will employ a diversity of reports utilizing a variety of media designed to appeal to a large audience.

Table 7-2. Summary of HTLN multi-faceted vital signs reports

Type of Report	Purpose of Report	Primary Audience	Review Process	Frequency
Annual Administrative Report and Work Plan	Budget and accounting. Operations plans for all monitoring projects. Administrative report used for annual report to Congress.	HTLN Board of Directors (BOD), Technical Committee, regional coordinators, and service-wide managers.	Reviewed and approved by BOD, regional coordinator, and service-wide program manager.	Annually
Protocol Review Reports	Assess and document the overall quality of protocol to be implemented. Specifically document the scientific soundness of the protocol, its effectiveness towards meeting the stated objectives, and completeness of SOPs.	Superintendents, park resource managers, HTLN staff, service-wide managers, and external scientists.	Informal peer-review by HTLN staff. Formal peer review by external scientists, conducted by regional coordinator.	Within 1 year of protocol completion
Program Review Reports	Assess and document the overall operations of the HTLN through a formal review process coordinated by the Technical Committee and regional coordinator.	Superintendents, park resource managers, HTLN staff, service-wide managers, and external scientists.	Reviewed at the regional and national level, HTLN BOD, and Technical Committee.	Every 5 years
Annual Status Reports for Specific Protocols	Summarize monitoring data collected during the year and provide an update on the status of selected natural resources. Document related data management activities and data summaries.	Park resource managers and external scientists.	Internal peer review by HTLN staff.	Annually

Table 7-2 continued

Executive Summary of Annual Reports for Specific Protocols	Same as *Annual Status Reports* but summarized to highlight key points for non-technical audiences.	Superintendents, interpreters, and the general public.	Internal peer review by HTLN staff.	Simultaneous with *Annual Status Reports*
Comprehensive Trends Analysis and Synthesis Reports	Describe and interpret trends in individual vital signs. Describe and interpret relationships between observed trends and park management, known stressors, climate, etc. Highlight resources of concern that may require management action.	Park resource managers and external scientists.	Internal peer review by HTLN staff.	Every 5 - 7 years
Executive Summary of Comprehensive Analysis and Synthesis Reports	Same as *Comprehensive Trends Analysis and Synthesis Reports*, but summarized to highlight findings and recommendations for non-technical audiences.	Superintendents, interpreters, and the general public.	Internal peer review by HTLN staff.	Simultaneous with *Comprehensive Trends Analysis and Synthesis Reports*
Scientific journal articles and book chapters	Document and communicate advances in knowledge.	External scientists and park resource managers.	Peer review by journal or book editor.	Variable
Symposia, workshops, and conferences	Review and summarize information on a specific topic or subject area. Communicate latest findings to peers. Identify emerging issues and generate new ideas.	External scientists, other state and federal agencies, and natural resource non-governmental organizations	None	Variable
HTLN Newsletter	Review and summarize network activities and findings of general interest. Describe the role and purpose of the network to non-technical audiences.	Park staff, NPS partners, and cooperators.	Reviewed by program coordinator.	Quarterly

Table 7-2 continued

State of the Parks Report	Describes current conditions of park resources. Reports interesting trends and highlights monitoring activities. Identifies situations of concern. Explores future issues and directions.	Congress, budget office, NPS leadership, superintendents, and the general public.	Compiled by WASO from data provided by networks.	Annually
HTLN internet web site	Centralized repository for all reports, monitoring information, metadata, and information on how to obtain monitoring data.	Superintendents, interpreters, park staff, NPS partners and cooperators, general public, other state and federal agencies, and natural resource NGOs.	Varies by report type (see above).	Reports will be posted as available.

Data Management Support for Analysis and Reporting

Reporting is the process through which we derive information from the underlying data through analysis and interpretation. As such, the quality of the information in the report is determined by the quality of the underlying data. The relationship between good information and good data necessarily includes an important role for data management in analysis and reporting. Databases will be as complete as possible and maintained by project leaders with the assistance of data managers. Additional data will often be required in order to complete the necessary analyses. Weather data, complete site information, taxonomic information, complete names of observers, and even database design changes, such as keys, indexes, and constraints, may be needed prior to analysis.

The automation of data summaries and annual reports facilitates the network's ability to manage multiple projects. HTLN uses Microsoft Access to automate data summaries and reports and produce descriptive statistics. We will export data from MS Access to statistical software packages for analyses beyond descriptive statistics. The project leader will coordinate with the staff's quantitative ecologist to determine the appropriate analyses.

Following the appropriate review process, dissemination of data, reports, and other items (photos, sound recordings, etc.) will be in accordance with service-wide NPS standards (see Table 7-3 for website locations with additional information). Species lists and voucher data are entered to NPSpecies and ANCS+ and subsequently updated (if required), whereas reports will be documented in NatureBib. Reports are currently being converted to Adobe .pdf files and posted on the HTLN website or at the Biodiversity Data Store. Metadata and monitoring geodatabases will be uploaded to the NR-GIS Metadata and Datastore for general distribution following quality assurance/quality control and metadata review. Special requirements for entering and managing water quality data in NPStoret are given at the service-wide NPS Water Resources website. Requests for information products can be made by contacting the HTLN data manager through the network website.

Table 7-3. NPS Network and service-wide web applications for reporting information products

NPS Service-wide website	Current URL (user id and password required on most sites)
HTLN website	http://www1.nature.nps.gov/im/units/htln/index.htm
NPSpecies	https://science1.nature.nps.gov/npspecies/
NatureBib	https://science1.nature.nps.gov/naturebib/ac/simple/clean
NR-GIS Metadata and Data Store	http://science.nature.nps.gov/nrdata/
Biodiversity Data Store	http://science.nature.nps.gov/im/inventory/biology/BiodiversityDataStore.htm
NPStoret	http://www.nature.nps.gov/water/infoanddata/index.htm

CHAPTER 9: SCHEDULE

This chapter describes the plan for implementing vital signs monitoring in the HTLN. A wide range of protocol development efforts are required to address the disparate resources stewarded by the member parks and to meet their high priority information needs. Protocols are complete for thirteen vital signs, and their implementation will begin in 2005. For the twelve protocols still under development, table 9-1 summarizes their status, and lists the remaining tasks before monitoring may be implemented with anticipated completion dates.

The monitoring plan must also accommodate a wide range of environmental and logistical circumstances when tailoring monitoring for each individual park. Therefore, issues such as the optimal time period for data collection (i.e., index period) and sampling frequency (i.e., the revisit plan) are specific to each park by protocol combination. For example, invertebrates are best sampled in early winter in Ozarks rivers, however, the optimal season for data collection in prairie streams is summer. Similarly, a core set of vegetation plots is sampled annually at TAPR; however, plots are visited on a rotating basis in other parks. Nonetheless, it is possible to generalize the index period, the revisit plan, and implementation schedule for each project (Table 9-2), recognizing that details regarding each park by protocol combination are available in Table 5.1.

Important work is being done by HTLN staff concurrent with protocol development in support of those efforts. A database management infrastructure for vital signs monitoring will integrate ongoing monitoring efforts of the prototype with new monitoring scheduled to begin in the near future. Similarly, HTLN staff is developing an infrastructure and overall framework for sample site selection to promote integration of monitoring projects through co-locating sample sites.

The implementation plan presented in table 9.2 will almost certainly evolve as protocols are completed and the logistical constraints of field work are learned. We will annually re-evaluate our progress and adjust the implementation plan as necessary.

Table 9-1. Summary of ongoing protocol development projects, remaining tasks and anticipated completion dates

Level 1	Level 2	Level 3	Network Vital Sign Name	Key Issues and Project Milestones
Air and Climate	Weather and Climate	Weather and Climate	Weather	• Consolidate weather service data and make available through a web site – Aug 05 • Final protocol for updating and maintaining data due from the principal investigator – Aug 06
Geology And Soils	Geomorphology	Stream/ River Channel Characteristics	Fluvial Geomorphology	• Receive final protocol from principal investigator - May 2005 • Complete construction of the sample frame and select monitoring sites – June 2005
		Surface Water Dynamics	Stream Discharge	• Consolidate USGS data and make available through a web site – Aug 05 • Final protocol for updating and maintaining data due from the principal investigator – Aug 06
	Water Quality	Water Chemistry	Pollutant Metals	• Revise project description to focus on lead – March 05 • Initiate interagency agreement to develop a monitoring protocol – June 05
		Aquatic Invertebrates and Algae	Aquatic Invertebrates—Rivers	• Complete a draft protocol narrative and SOPs - June 2005 • Complete construction of the sample frame and select monitoring sites – June 2005 • Conduct pilot study (test methods, assess logistics) – Dec 2005 • Complete final protocol narrative and SOPs – August 2006
Biological Integrity	Invasive Species	Invasive/Exotic Plants	Exotic Forest Plants	• Complete prioritization database, identify target species – May 2005 • Develop park specific monitoring plans (first 3-5 parks) – Oct 2005 • Conduct pilot study to test methods and assess logistics – Aug 2006 • Complete monitoring protocol and SOPs – Aug 2007
		Invasive/Exotic Plants	Exotic Grassland Plants	• Same as above
	Focal Species or Communities	Wetland Communities	Wetland Plant Communities	• Draft protocol due from principal investigator - May 2005 • Final protocol due from principal investigator – Dec. 2005
		Fishes	Fish Community—Ozark Rivers	• Complete construction of the sample frame and select monitoring sites – June 2005 • Final protocol due from principal investigator – Aug. 2005
		Mammals	Deer	• Complete draft protocol narrative and SOPs – Jan. 2005 • Conduct pilot study at three parks – March 2005 • Complete final monitoring protocol and SOPs – Jan. 2006
		Threatened and Endangered Species and Communities	Ozark Hellbender	• Feb 2005, Nov 2005 & April 2005 – Interim reports • Complete construction of the sample frame and select monitoring sites – June 2005 • Draft protocol due from principal investigator – Oct 2006 • Final protocol due from principal investigator – Dec. 2006
Ecosystem Patterns and Processes	Land Cover and Use	Land Cover and Use	Land Cover/Land Use	• Interim report due from principal investigator – Sep. 2005 • Draft protocol due from principal investigator – Sep. 2006 • Final protocol due from principal investigator - Dec 2006

Table 9-2. Index period, general revisit plan and implementation schedule for vital signs monitoring (R&D = protocol research and development, PS = pilot study, X = monitoring implemented)

Level 1	Level 2	Level 3	Network Vital Sign Name	Index Period	Revisit Plan*	Implementation Schedule				
						2005	2006	2007	2008	2009
Air and Climate	Air Quality	Ozone	Ozone	Year round	Continuous	X	X	X	X	X
		Wet and Dry Deposition	Wet and Dry Deposition	Year round	Continuous	X	X	X	X	X
		Visibility and Particulate Matter	Visibility and Particulate Matter	Year round	Continuous	X	X	X	X	X
	Weather and Climate	Weather and Climate	Weather	Year round	Continuous	R&D	X	X	X	X
Geology And Soils	Geo-morphology	Stream/ River Channel Characteristics	Fluvial Geomorphology	TBD	[1-0,1-4]	R&D, PS	PS, X	X	X	X
			Stream Habitat/ Riparian Assessment	1 June – 1 Oct	[2-5]	X	X	X	X	X
		Surface Water Dynamics	Stream Discharge	Year round	Continuous	R&D	X	X	X	X
	Water Quality	Water Chemistry	Core Water Quality Parameters	TBD	Annual	X	X	X	X	X
			Pollutant Metals	TBD	[1-0,1-4]	R&D	R&D	X	X	X
		Aquatic Invertebrates and Algae	Aquatic Invertebrates—Prairie Streams	1 June – 1 Oct	Annual	X	X	X	X	X
			Aquatic Invertebrates—Rivers	1 Oct. – 1 Mar.	[1-0,1,4]	R&D, PS	PS, X	X	X	X
Biological Integrity	Invasive Species	Invasive/Exotic Plants	Exotic Forest Plants	15 Apr – 15 Oct	[1-5]	R&D	R&D, PS	R&D, PS	X	X
		Invasive/Exotic Plants	Exotic Grassland Plants	15 Apr – 15 Oct	[1-5]	R&D	R&D, PS	R&D, PS	X	X
	Focal Species or Communities	Wetland Communities	Wetland Plant Communities	TBD	TBD	R&D	PS	X	X	X
		Grassland Communities	Prairie Community Structure, Composition, and Diversity	15 Apr – 15 Oct	[2-3]	X	X	X	X	X
		Forest Vegetation	Forest Community Structure, Composition, and Diversity	15 Apr – 15 Oct	[2-3]	X	X	X	X	X
		Fishes	Fish Community—Prairie Streams	1 Sep – 15 Oct	[1-0,1-4]	X	X	X	X	X
			Fish Community—Ozark Rivers	1 Oct. – 1 Mar.	[1-0,1-4]	R&D, PS	PS, X	X	X	X
		Birds	Landbirds	1 May – 30 Jun	Annual	X	X	X	X	X
		Mammals	Deer	TBD	TBD	R&D, PS	R&D, X	X	X	X
		Threatened and Endangered Species and Communities	Missouri Bladderpod	1 Sep – 15 Jun	Annual	X	X	X	X	X
			Ozark Hellbender	TBD	[1-0,1-2]	R&D	R&D	X	X	X
			Topeka Shiner	1 Sep – 15 Oct	Annual	X	X	X	X	X
			Western Prairie Fringed Orchid	1 Jul – 31 Jul	Annual	X	X	X	X	X
Ecosystem Patterns and Processes	Land Cover and Use	Land Cover and Use	Land Cover/Land Use	NA	NA	R&D	R&D	X	X	X

*Notation follows McDonald, T. L. 2003. Environmental Trend Detection: A Review. Environmental Monitoring and Assessment **85**:277-292. See Chapter 4 for an explanation.

CHAPTER 10: BUDGET

Several sources of funding are combined to support operations of the HTLN. The two principle sources are vital signs monitoring funds from the Natural Resource Challenge ($652,000) and funds dedicated to operations of the Prairie Cluster Prototype ($505,000). In addition, NPS Water Resources Division contributes $82,000 for water quality monitoring. For the past several years, FIREPRO (an interagency organization overseeing fire operations and fire effects monitoring) has provided funds for joint monitoring efforts in Great Plains parks ($44,909) (Table 10-1).

Natural Resource Challenge funds for the program are held in Washington Office base accounts and transferred annually through the Midwest Regional Office. Funds to operate the prototype program have been permanently added to WICR base accounts. FIREPRO funds are transferred annually to WICR through the Midwest Regional Office. Discrete program work element codes are used to track projects and other expenditures as appropriate. Funds contributed by parks and other NPS programs are tracked using discrete cost codes. All funds are managed by the program coordinator under the oversight of the Board of Directors (BOD). Funds are used solely for purposes of operating the program in a way consistent with NPS policies, rules, and regulations.

An annual work plan is developed with input from the Network Technical Committee (NTC) and approved by the BOD that directs expenditure of funds to projects, parks, and offices. All I&M program funds must be strictly accounted for using discrete project work element (PWE) codes and disclosed in an Annual Administrative Report.

Table 10-1. Funding for operations of the I&M program, its location, and associated full time equivalents (FTE)

Funding Source	Funds Held By:	Amount	FTE
vital signs monitoring	WASO	652,000	6
Water Resources Division – water quality monitoring	WASO	82,000	0
prototype monitoring	WICR	505,000	7
FIREPRO	FIREPRO	44,909	1.4
Total		**1,283,909**	**14.4**

Personnel costs account for the majority of expenditures, which is consistent with our intention to implement monitoring primarily through NPS staff. In FY 2006, the first year following approval of the monitoring plan and the first full year of earnest implementation, salary for permanent staff will account for 62% of the budget (Table 10-2). Total personnel cost for FY 2006 include the term data manager, seasonal biotechnicians, and salary for the following permanent I&M positions:

- administrative support assistant
- aquatic resources monitoring leader
- botanist
- botanist STF
- data manager
- fishery biologist
- GIS specialist
- plant ecologist
- program coordinator
- quantitative ecologist
- wildlife ecologist

The approved organization chart for the HTLN includes several additional permanent positions that are subject-to-furlough: two aquatic ecologists, and two biologist (see Chapter 8). With a complete staff at full performance level, personnel cost will account for 84% of the budget (Table 10-3).

Table 10-3. Projected budget at full staffing level (calculated with all staff at full performance level, step 5 with benefits estimated at 40% of gross salary)

Expense Category	Amount	Proportion
Permanent personnel	$1,076,000	84%
Temporary and seasonal personnel	$58,000	5%
Contracts and cooperative agreements	$10,000	1%
Operations and equipment	$82,000	6%
Travel	$60,000	5%

Table 10-3. Projected budget at full staffing level (calculated with all staff at full performance level, step 5 with benefits estimated at 40% of gross salary)

Expense Category	Amount	Proportion
Permanent personnel	$1,076,000	84%
Temporary and seasonal personnel	$58,000	5%
Contracts and cooperative agreements	$10,000	1%
Operations and equipment	$82,000	6%
Travel	$60,000	5%

For the model of a centralized staff to be successful, adequate travel funds are required to ensure monitoring data are collected. Furthermore, to maintain close communication between network and park staff, the BOD, and the NTC, annual face-to-face meetings are planned. In FY 2004, the HTLN spent $18,200 on field travel and an additional $41,800 on training, meetings, and conferences. To ensure adequate travel funds are available to support operations of the program, $60,000 (5% of the program budget) is earmarked for travel.

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Glossary

Adaptive Management is a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. Its most effective form-"active" adaptive management-employs management programs that are designed to experimentally compare selected policies or practices, by implementing management actions explicitly designed to generate information useful for evaluating alternative hypotheses about the system being managed.

In an **always revisit** or complete revisit designs, each sampling unit is revisited on each occasion.

Area frames are typically designated by geographical boundaries within which the sampling units are defined as subareas.

Attributes are any living or nonliving feature or process of the environment that can be measured or estimated and that provide insights into the state of the ecosystem.

A **cluster sample** describes an approach whereby selection is made of groups or clusters of units, called primary units, within which all of the secondary units are sampled (Levy and Lemeshow 1999).

Co-location refers to sampling the same physical units in multiple monitoring protocols.

Co-visitation refers to sampling the same units for multiple vital signs on the same occasion, thus reducing travel costs.

Domains represent subpopulations of interest, are typically not known until after the sample is drawn.

A **dual frame** design incorporates more than one sampling frame.

Ecological integrity is a concept that expresses the degree to which the physical, chemical, and biological components (including composition, structure, and process) of an ecosystem and their relationships are present, functioning, and capable of self-renewal. Ecological integrity implies the presence of appropriate species, populations and communities and the occurrence of ecological processes at appropriate rates and scales as well as the environmental conditions that support these taxa and processes.

Ecosystem is defined as, "a spatially explicit unit of the Earth that includes all of the organisms, along with all components of the abiotic environment within its boundaries" (Likens 1992).

Ecosystem drivers are major external driving forces such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts, floods) that have large scale influences on natural systems.

Ecosystem management is the process of land-use decision making and land-management practice that takes into account the full suite of organisms and processes that characterize and comprise the ecosystem. It is based on the best understanding currently available as to how the ecosystem works. Ecosystem management includes a primary goal to sustain ecosystem structure and function, a recognition that ecosystems are spatially and temporally dynamic, and acceptance of the dictum that ecosystem function depends on ecosystem structure and diversity. The whole-system focus of ecosystem management implies coordinated land-use decisions.

An **element** consists of any item for which measurement is made or information is recorded (Lohr 1999).

Focal resources are park resources that, by virtue of their special protection, public appeal, or other management significance, have paramount importance for monitoring regardless of current threats or whether they would be monitored as an indication of ecosystem integrity. Focal resources might include ecological processes such as deposition rates of nitrates and sulfates in certain parks, or they may be a species that is harvested, endemic, alien, or has protected status.

Frame error occurs when the sampled population does not coincide with the target population (Lesser and Kalsbeek 1999).

The **Generalized Random Tessellation Stratified** (GRTS) design is based on creating a function that maps two-dimensional space onto one-dimensional space, and uses a restricted randomization algorithm to produce a sample that is well balanced, yet randomly selected (Stevens and Olsen 2004).

Haphazard sampling, sometimes referred to as convenience sampling, is generally based on such factors as ease of access. As such, there is no assurance that samples drawn in this manner will be representative of the overall target population.

Indicators are a subset of monitoring attributes that are particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2002). Indicators are a selected subset of the physical, chemical, and biological elements and processes of natural systems that are selected to represent the overall health or condition of the system.

Judgment sampling entails selection of sampling units based on expert knowledge, but selection bias is common when judgment sampling is used (Edwards 1998, Stoddard et al. 1998, Olsen et al. 1999).

List frame is a list of the potential sampling units along with their descriptive attributes.

Measures are the specific feature(s) used to quantify an indicator, as specified in a sampling protocol.

A **membership design** is defined as the plan by which sample units become members of a particular panel of sample units.

In a **never revisit** design a different sampling unit is visited on each occasion and never visited again.

A **panel** is a group of sample units that are always sampled during the same sampling occasion.

Probability-based samples apply sampling theory and some means of randomization of sample unit selection (EPA 2002).

Pseudoreplication occurs when subsamples or elements are treated as independent samples.

Revisit design defines the way sampling effort will rotate among panels through time (McDonald 2003).

A **rotating** or repeating panel design specifies that all panels are sampled for x years, then not sampled for y years.

Sampled population is the actual population from which the given sample is drawn. As discussed below, ideally it would coincide with the target population and the sample frame, but a perfect correspondence of these is rarely possible in environmental settings.

Sample frame is any material or device used to obtain observational access to the target population (Sarndal et al. 1992).

Sample units are the individual units contained within the frame that are actually sampled.

A **simple random sample** is a method in which n units are selected from a population of size N via a random process, such that every sample unit has the same probability of being included in the sample.

A **split panel** design partitions (splits) the panels into two or more revisit designs

Strata refer to subpopulations that are defined before the sample is drawn and are used primarily to distribute sample points.

Stressors are physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive [or deficient] level (Barrett et al. 1976:192). Stressors cause significant changes in the ecological components, patterns and processes in natural systems. Examples include water withdrawal, pesticide use, timber harvesting, traffic emissions, stream acidification, trampling, poaching, land-use change, and air pollution.

A **stratified random sample** is a method in which the sampling frame is divided into mutually exclusive and exhaustive subpopulations called strata from which n samples are randomly selected from each strata (Levy and Lemeshow 1999).

Subpopulation refers to a subset of units or elements that may be of particular interest.

A **systematic sample** is a sampling method in which one subject is typically selected at random and subsequent subjects are selected according to a systematic pattern. A common form of systematic sampling is randomly selecting one unit from the first k units in the sampling frame and every kth unit thereafter (Mendenhall et al. 1971).

Target population consists of the entire collection of units or elements for which inference is intended.

Vital Signs, as used by the National Park Service, are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes).

Abbreviations and Symbols

ARD - Air Resources Division (National Park Service)
ARPO - Arkansas Post National Memorial
ASCII - American Standard Code for Information Interchange
BBS - North American Breeding Survey
BOD - Board of Directors (HTLN)
BRD - Biological Resources Division (National Park Service)
BUFF - Buffalo National Scenic River
C - Celsius
CASTNet - Clean Air Status and Trends Network
CEM - conceptual ecological model
CESU - Cooperative Ecosystem Studies Units
CUVA - Cuyahoga Valley National Park
DLG - digital line graph
EFMO - Effigy Mounds National Monument
e.g. - exempli gratia/example give
EPA - Environmental Protection Agency
EPT Ephemeroptera, Plecoptera, Trichoptera
ERD - Entity relationship diagram
FirePro - fire program (National Park Service)
FOIA - Freedom of Information Act
FTE - full time equivalent
GIS - geographic information system
GPRA - Government Performance and Results Act
GPS - global positioning system
GRTS design - generalized randomized tessellation stratified design
GWCA - George Washington Carver National Monument
H' - Shannon species diversity index
Hg - mercury
HEHO - Herbert Hoover National Historic Site
HOCU - Hopewell Culture National Historic Park
HOME - Homestead National Monument of America
HOSP - Hot Springs National Park
HTLN - Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program
I&M - inventory and monitoring

IMPROVE - Interagency Monitoring of Protected Visual Environments
J' - species evenness (as used in Shannon diversity index)
km - kilometer
LIBO - Lincoln Boyhood National Memorial
mi - miles
MWR - Midwest Region
NA - not applicable
NAAQS - National Ambient Air Quality Standards
NADP - National Atmospheric Deposition Program
NGPN - Northern Great Plains Network
NPS - National Park Service
NPWRC - Northern Plains Wildlife Research Center (United States Geological Survey)
NRC - National Research Council (United States)
NTC - network technical committee
NWS - National Weather Service
OZAR - Ozark National Scenic Riverways
Pb - lead
PC-LTM - Prairie Cluster Prototype Monitoring Program
PDS - protocol development summary
P.I. - principal investigator
PIPE - Pipestone National Monument
PERI - Pea Ridge National Military Park
PWE - project work element
QA/QC - quality assurance/quality control
RAID 5 - redundant array of independent disks 5
SCEP -
SMSU - Southwest Missouri State University
STEP -
SOP - standard operating procedure
STORET - Storage and Retrieval Database
STF - subject to furlough
TAPR - Tallgrass Prairie National Preserve
TBD - to be determined
TMDL - total maximum daily load
U.S. - United States
USGS - United States Geological Survey
UTM - Universal Transverse Mercator
WASO - Washington Office (National Park Service)
WICR - Wilson's Creek National Battlefield